BLACK HOLES
IN OUR MILKY WAY
p. 44

EXCLUSIVE INTERVIEW BIO:
BRIAN MAY
HIS LIFE IN ASTRONOMY AND QUEEN'S MUSIC p. 26

September 2012

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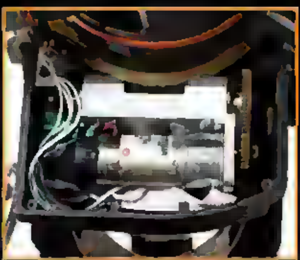
Telescopes, Eyepieces, Astrographs – Gregory Hallock Smith, Roger Ceragioli and Richard Berry



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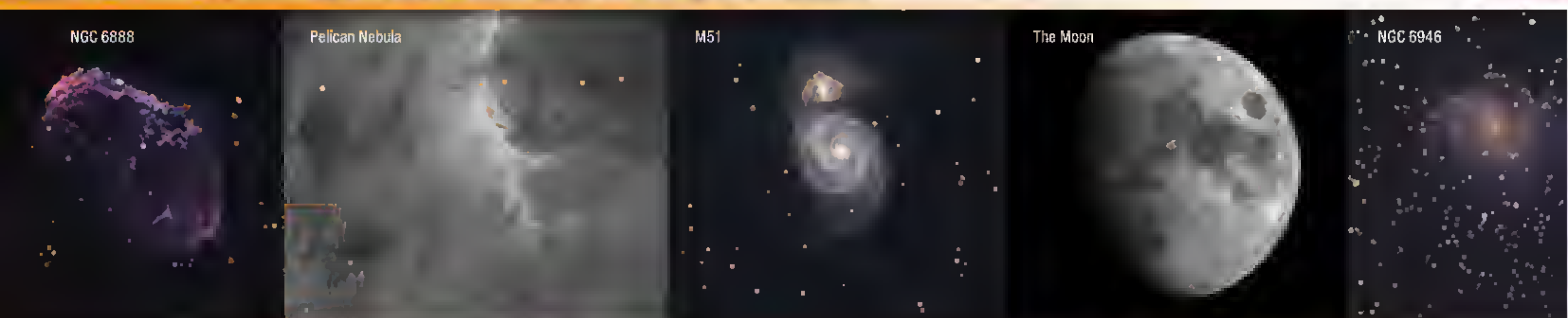

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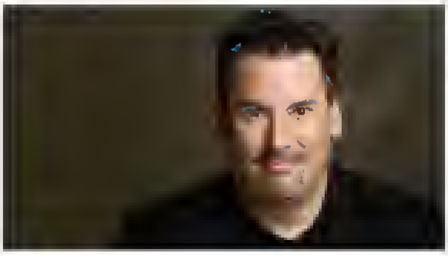
This Month in *Astronomy*

The Queen "A Kind of Magic" Contest



by David J. Eicher

If you flip to page 26, you'll see my story "Brian May: A life in science and music." The Queen guitarist, singer, and songwriter is also a Ph.D. astrophysicist and a member of *Astronomy*'s Editorial Advisory Board. Brian's life story is thus unique — a tale of working on the motions of dust particles in the solar system interrupted by 30-plus years of rock 'n' roll, with a return to finish his dissertation.

The story in this issue is the first time Brian May's life has been described wherein astronomy and worldwide musical success have an equal footing. (And you can read a much longer, 8,500-word version of the story online at www.Astronomy.com/toc.)

To celebrate the occasion, Brian and *Astronomy* magazine are holding an event. The Brian May/Queen "A Kind of Magic" Contest is open from August 1 through September 1, 2012. As I've described, Brian left his nearly finished doctoral degree on the table when Queen began achieving huge success and set off on an aggressive schedule of making albums and touring. Brian's returning and finishing his Ph.D. is a rarity, only possible because the subject hadn't changed a lot over the previous three decades.

I don't know what each of you does, but most readers of *Astronomy* are not Ph.D. astronomers. Whatever your occupation, I want you to think creatively. Contest entrants will submit a short essay to the magazine that describes what they would do — what would the subject be and why? — if they could magically go back to school and earn a doctoral degree in astronomy.

How would you change the astronomy world? What research subject would entice you? Planetary science? Cosmology? Galaxy investigations? And what specifically would you take on as a line of research? (And for those of you who are Ph.D.s and want to enter, you simply can imagine what you might do if you got a second degree in a different area of research. Ha!)

The two best essays will win a prize for the writers — an autographed copy of Brian May's Ph.D. dissertation, *A Survey of Radial Velocities in the Zodiacal Dust Cloud*, which was published by Springer-Verlag in 2008. For full details on the contest and to enter, see www.Astronomy.com/akindofmagic.

The contest's name, of course, comes from the hit song "A Kind of Magic" from Queen's album of the same name, released in 1986. The accompanying huge-scale Magic Tour would be the last with all four band members. Of the tour, Brian says, "We just had it right and felt that finally we knew how to play live, we knew how to connect with the audience. It all just felt like joy. I think it was the best I've ever played. And Freddie Mercury was magnificent in those times; the perfect athlete, the perfect front man, the perfect link to the audience. I just remember it as being a blur of good feelings." You can see the choice show from this tour on the DVD *Queen Live at Wembley Stadium*.

For more on Queen and on Brian's astronomy, check out the story on page 26.

Yours truly,

David J. Eicher
Editor

Astronomy.

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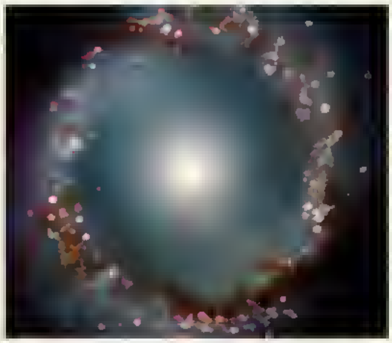

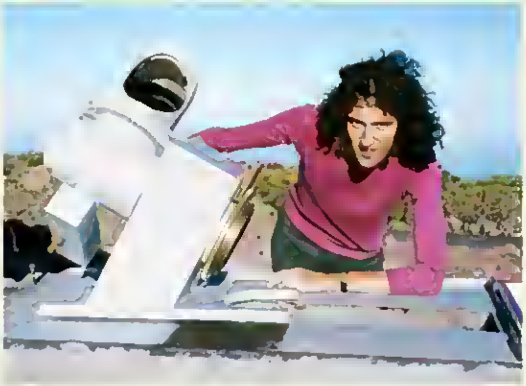

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ON THE COVER

Astronomers are in a race to find the first structures that formed. These aren't the huge galaxies of today, but instead smaller and simpler protogalaxies.

COLUMNS

IN EVERY ISSUE

Letters

We welcome your comments at Astronomy Letters, P. O. Box 1612, Waukesha, WI 53187; email to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.

Important numbers

After reading "The 6 most important numbers in the universe" (June 2012), I thought I'd share a story from my youth. Several "tens of years ago," I was taught to reduce numbers to powers of 10 to estimate an answer. I was told to express each number as a single digit and its power of 10 — adding powers to multiply and subtracting them to divide, then doing the single digit in my head. I learned that if I got the right power of 10, the maximum I could be off is 10 percent and I'd be within 90 percent of correct. And it works. Sadly, nobody estimates anymore — they use calculators. — **Alan Dooley,** Waterloo, Illinois

Conspicuous by its absence in your set of important numbers in the June issue is *e* (e = 2.7182818 …), the base of natural logarithms. By itself, that value doesn't seem very impressive, but the constant permeates nature: It appears in the way a pot of coffee (or anything else) cools off, how radioactive materials decay, how heat spreads, how interest (and bacteria and populations) grow, and how a chain hangs. The constant *e* is part of the nature of waves, spirals, and attenuation of light or sound; those are just a few examples. I would bet that in any textbook about thermodynamics, (astro)physics, chemistry, engineering, etc., you will encounter *e* before you see π for the first time. — **Hans Schroeder,** Milwaukee, Wisconsin

Space exploration

I just want to thank you for printing the article of Brian May's speech at the STARMUS Festival in the Canary Islands ("What are we doing in space?" February 2012). In a world where politicians seem to discuss everything but real issues, it was refreshing to read his intelligent and eloquent words about the current state of our planet before we explore (and desecrate!) others. The article covered such a variety of social and political issues that are completely relevant to the continuation of our investigation of other planets.

It seemed like he was hesitant to give the speech, and I would love to know how it was received. Brian, thank you for the courage you showed by putting your opinion out there. You are well-versed in both music and science, and that is truly a unique set of talents, but even more significant is that you are also a conscientious human being who cares about Earth and the life that inhabits it. Keep talking — some of us are listening. — **Kevin Whitson,** Wood Dale, Illinois

It was interesting to contrast the articles on future space exploration by a pessimistic Brian May and an optimistic Robert Zimmerman ("Will we go back to the Moon?") in the February issue. (I'll note that May ended on a guardedly hopeful tone.) I think reality will show itself to be somewhere in between their views. We'll go into space with all of our baggage eventually following us, unless deliberate steps are taken to control that. — **Spence Blakely,** Portsmouth, Rhode Island

Correction

The reference to LEGOs in the June 2012 Cosmic Grid (page 74) states the wrong country of origin: The LEGO company is based in Denmark. — ***Astronomy* editors**

What's new at Astronomy.com. **by Karri Ferron**

Featured video

"Tour the solar system: Uranus"

Uranus, everyone's favorite oddball planet, reaches opposition in September, making now the best time to view and photograph it. But what do scientists know about this blue-green world that seems to roll around the Sun on its side? Associate Editor Liz Kruesi provides an overview in "Tour the solar system: Uranus." The first planet discovered in modern times, Uranus is an enigma in our planetary neighborhood. In the video, Kruesi provides the basic parameters of the world; explains how scientists think it ended up with a rotation axis nearly parallel to its orbit; explores its ring system, family of moons, and atmosphere; and more.

This video and all others in the *Tour the solar system* series are available to registered members of Astronomy.com. Registration is free and easy, so sign up today and head to **www.Astronomy.com/solarsystem** to learn more about this oddball planet.

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by Bob Berman

Believe it?

Sometimes the truth is just what you have the space and time to explain.

I'm a liar. I can't help it. Each page I write has something wrong to a degree and — no surprise — readers often catch on. "Two months ago, you wrote that the solar system is heading toward the star Deneb in Cygnus. But my textbook says we're actually moving toward Vega in Lyra."

That person was right. But so was I. How can two conflicting statements both be correct? That's this month's subject.

The Milky Way's rotation swiftly carries the Sun and Earth toward Deneb. However, if one merely considers the 200 nearest stars around us in space, we have a separate little motion *relative to them*. This slow sideways drift is toward Vega; some say the constellation Hercules. Years ago, scientists only knew that local motion.

The problem — and it never ends — is limited space. If science writers pause to fully explain such facts, we'll never get to the point of the article. Hence, much that appears in science magazines is true *in just one sense*. Falsehoods include the simplest "facts" everyone thinks they know.

For example, we say Earth rotates in 24 hours. However, our planet actually spins in 23 hours, 56 minutes, and 4.1 seconds. The discrepancy isn't caused by rounding off. Clocks are deliberately built to include an extra few minutes of spin. This compensates for Earth's orbital path, which places the Sun toward a new direction each day. If we want Sol to always be highest when clocks say noon, we must let Earth spin once completely and then add an extra 3 minutes and 55.9 seconds of rotation. Only then will we face the Sun at the same clock time the next day. Timepieces were thus designed to keep our lives aligned with the Sun. Don't imagine that they register our actual rotation.

The sky is blue, right? Well, buy a spectroscope on eBay. This wonderful instrument reveals what's really in the light we see. Point it at the daytime heavens. Bam — all the colors of the rainbow. Vivid greens and oranges come from the sky. Its composition resembles sunlight, but with red scattering four times less than blue, the latter color is visually dominant. So it's not strictly correct to say, "The sky *is* blue." It would be better to say, "The sky *looks* blue."

But that's probably too picky. After all, we happily say, "The Sun is rising," despite knowing that "the horizon is falling" would be more accurate. We don't want to sound stilted or obnoxious. Still, shouldn't we draw the line when a statement is more wrong than right?

Much that appears in science magazines is true *in just one sense*.

Consider the expanding universe. Cosmic expansion would seem as straightforward as blowing up a party balloon. Actually, it's not like that at all. Turns out, the cosmos inflates only on the largest scales, which itself is odd. Within solar systems, star clusters, individual galaxies, and among all the stars visible in the night sky, there's no expansion whatsoever. You could travel 3 million light-years and not encounter the slightest hint of expansion. As a result, people are seriously puzzled. They ask how galaxies can possibly collide if the universe is expanding. Such confusion arises because we rarely mention that an "expanding universe" doesn't apply to each cluster of galaxies and all its contents.

Another oft-repeated fact is that light has a constant speed. It's true in a vacuum. But it goes 25 percent slower through most liquids, which is why a spoon seems bent in a half-glass of water. But is light really slower then? Kind of. It does take longer to pass through water. However, light photons still move at

In water, light travels 25 percent slower than it would in a vacuum, making a spoon appear bent in a glass of the liquid. But does that mean light doesn't have a constant speed? Hemera/Thinkstock

their previous superfast speed *between* water molecules. They're absorbed and then reradiated only when they hit atoms, and this process takes a bit of time. So are photons *really* moving slower within water or not?

Such nuances can't be clarified in a few words. If I fully explain, any article will read like the legalistic "don't use your new laptop in a hot tub" part of an instruction booklet. The alternative is to be flat-out wrong in some way. There's no good solution.

Does Jupiter orbit the Sun? Actually, it orbits the barycenter where the jovian and solar gravities balance. Have you ever seen a meteor? Actually, you've seen only the glowing air around the seed-sized meteoroid.

Excessively condensed science is everywhere. You've always read that humans breathe out carbon dioxide. Turns out, we exhale roughly 78 percent nitrogen, 17 percent oxygen, 4 percent carbon dioxide, and 1 percent argon. We exhale far more oxygen than carbon dioxide. Performing mouth-to-mouth to fill someone's lungs with our air would be pointless if there wasn't a lot of oxygen in that offering.

It's downright misleading to say, "Outbreaths are carbon dioxide." Yet no science writer has ever to my knowledge taken the time to clarify this.

So next time you spot something suspicious, be aware that science prose is simplified for brevity and filled with trade-offs. (And, on this page, designed to sneak in some cool little-known facts.) Is everything totally true?

Yes, sure. Also, no.

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by Glenn Chaple

Lunar letters

A First Quarter Moon offers observers countless targets, including two special letters.

First Quarter or half Moon — which is the correct name of the lunar phase that occurs one week after New Moon? Astronomers prefer the former while poets and dreamers opt for the latter. One of my goals as a middle school science teacher was to stamp "quarter Moon" into the impressionable young minds of my students. I had a tactic. I'd begin by saying, "Notice that First Quarter phase occurs when the Moon has traveled *one quarter* of the way around Earth since New Moon." Then I'd add, "During First Quarter, we only see half of the one-half of the Moon that faces Earth. Half of one-half equals *one quarter* of the entire Moon." Mission accomplished! Or so I thought.

One day, one of my more astute students raised his hand. "If that's the case, why do we call the Full Moon 'full' when it's only gone *halfway* around Earth and we can only see the *half* of the Moon that faces us?" You could almost hear the "whoosh!" as the wind left my sails. When it comes to naming lunar phases, I have to admit that the poets and dreamers got this one right.

The First Quarter Moon ("first half," if you prefer) is a breathtaking telescopic sight. Up and down the length of the terminator (the boundary between day and night on the Moon), our eyes feast on a spectacular jumble of craters and mountains whose rugged topography is enhanced by the long shadows of a lunar morning. On the nighttime side of the terminator, bright specks and shapes punctuate the darkness as the rising Sun illuminates mountain peaks and lofty regions. One of the more intriguing of these shapes is the Lunar X.

The Lunar X appears when sunlight strikes an elevated area at the junction of the craters La Caille, Blanchinus, and Purbach. I had viewed the First Quarter Moon hundreds of times in the past without ever noticing this remarkable feature. I still might be clueless as to its existence had it not been for *Astronomy* Senior Editor Michael E. Bakich and Contributing Editor Phil Harrington. Bakich described the Lunar X in his October 2009 *Astronomy* article "Explore 12 great lunar targets" while Harrington mentioned it in his book *Cosmic Challenge* (Cambridge University Press, 2010).

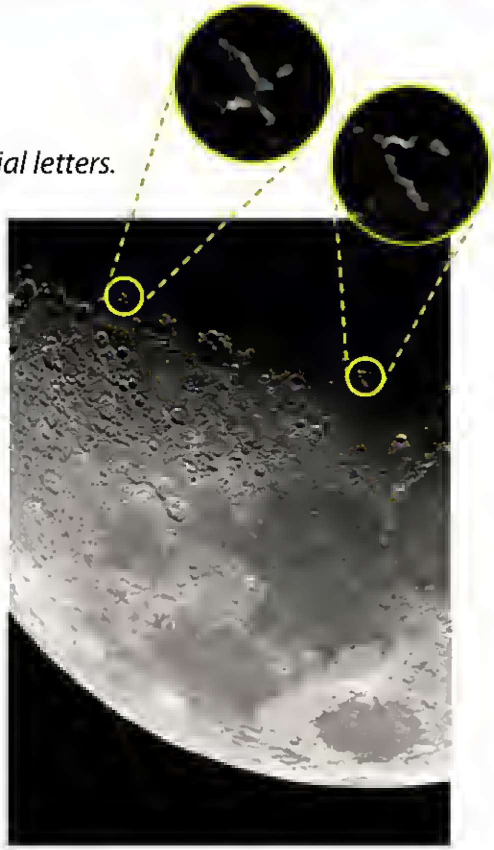
I first saw the Lunar X during a star party last spring. Thanks to a timetable in *Cosmic Challenge*, I knew the X would be visible that evening. I pointed my telescope toward the Moon and peered into the eyepiece. There, standing out from the darkness about a quarter of the way up from the Moon's south pole, was a bright X. What an amazing sight, and surprisingly easy to see!

How could such an obvious feature have eluded so many observers? Sensory overload is one culprit. The First Quarter Moon displays so much detail that we often fail to notice subtle, yet striking features. Timing is another factor. The window of visibility for the Lunar X lasts a mere four hours.

In September, the Lunar X will be in full view on the 22nd during the hours centered on 21h46m UT (5:46 P.M. EDT). These circumstances favor observers in the eastern parts of North and South America (after the Sun sets) and Western Europe and Africa. Those in eastern Asia and Australia will get their turn next month (October 22 around 11h08m UT). Because of the 29½-day cycle of lunar phases, conditions favorable for seeing the X from a particular location on Earth occur roughly every other month.

Amazingly, during those precious few hours of Lunar X visibility, observers can spot another letter. If you focus your attention on the part of the terminator near the lunar equator, you'll see a distinct letter V. Like the X, the Lunar V is a transient phenomenon — in this instance created by sunlight striking high elevations near a pair of intersecting ridges between Mare Vaporum and Sinus Medii.

Whether you're a novice or a veteran skygazer who has a "been there, done that" attitude about the Moon, be sure to pen in the Lunar X and V on your "must-see" list. The two are accessible to anyone, regardless of experience. They are within the grasp of the smallest telescope magnifying as low as 20x. Once you've seen them, you'll agree that the letters V and X stand for Very X-traordinary!



The Lunar X and the Lunar V (circled) are both visible for a few hours each month at First Quarter Moon. Ziad El-Zaatari

Another important lunar event happens September 22. This is the date of the second International Observe the Moon Night (InOMN), a worldwide outreach event sponsored by a dedicated team of scientists, educators, and lunar enthusiasts. Through InOMN, they hope to instill in the public a sense of wonderment and curiosity about the Moon. For information on InOMN activities in your area or ways you can conduct your own InOMN event, go to http://observethemoonnight.org.

Questions, comments, or suggestions? Email me at gchaple@hotmail.com. Next month: astroimaging with a cellphone and a telescope. Clear skies!

Browse the "Observing Basics" archive at www.Astronomy.com/Chaple.

Marvelous MIRI NASA received the Mid-Infrared Instrument (MIRI) for the upcoming James Webb Space Telescope (Hubble's successor) in a ceremony May 9.

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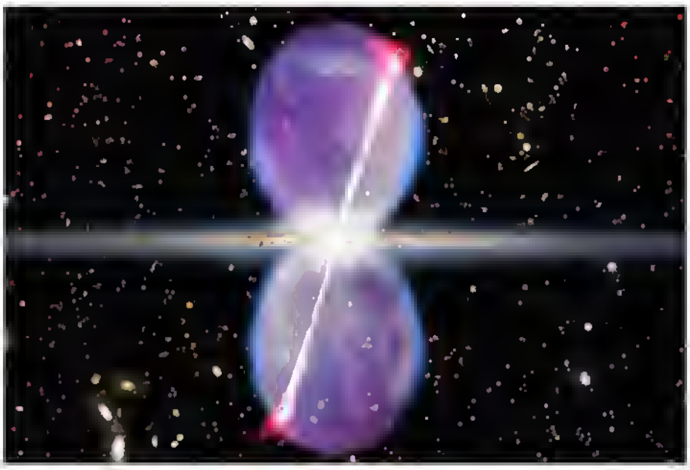
Astronews

Faint jets suggest past Milky Way activity

Astronomers have long considered our home, the Milky Way Galaxy, a relatively quiet place. But newly discovered ethereal gamma-ray beams bursting from our galaxy's center, combined with a 2010 finding of unexpected gamma-ray bubbles emanating from the same location, may indicate that our galaxy was much more active a relatively short time ago. Details about the beams and their implications will appear in an upcoming issue of *The Astrophysical Journal*.

"These faint jets are a ghost or after-image of what existed a million years ago," says lead author Meng Su of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts. "They strengthen the case for an active galactic nucleus in the Milky Way's relatively recent past."

NASA's Fermi Gamma-ray Space Telescope discovered both the beams and the bubbles of two years ago. The former stretch about 27,000 light-years above and below the galactic plane, at an angle of 15°; these are the only such jets known. The bubbles also happen to extend 27,000 light-years from the center of our galaxy, but do so perpendicularly to the plane.



David A. Aguilar (CfA)

Bubbles 'n' beams. Twin gamma-ray bubbles (purple) and newly discovered twin gamma-ray beams (pink) emanate from the Milky Way's center, as shown in this illustration. Together, they indicate that our galactic center may have been much more active in the recent past.

The two structures may be related, but they almost certainly formed differently. The beams likely resulted from hot matter squeezing through the tight magnetic field of the galactic center while the bubbles probably formed from the push of material spewing from the Milky Way's central black hole. More research is necessary to understand these structures. — **BILL ANDREWS**

Mars capable of producing organic carbon

Researchers studying martian meteorites have found that the Red Planet is capable of producing organic carbon. Also known as reduced carbon, this substance is an important ingredient in the formation of life, but it remains unclear whether Mars has ever had any biological activity. The findings, which should help scientists search for signs of such activity, appeared in a *Science* Express paper published online May 24.

"These findings show that the storage of reduced carbon molecules on Mars occurred throughout the planet's history and might have been similar to processes that occurred on the ancient Earth," says lead author Andrew Steele of the Carnegie Institution for Science in Washington, D.C.

Similar molecules, composed of large chains of carbon and hydrogen atoms, had been found before in martian meteorites, but scientists didn't know if the carbon originated on Mars. After studying 11 meteorites, which spanned about 4.2 billion years of martian history, Steele's team found large carbon compounds in 10 and proved that the carbon resulted from natural processes on Mars.

Don't forego orgo. Scientists have learned that Mars can form organic carbon, a fact that might help the Curiosity rover detect evidence of biological activity, as illustrated here. NASA/JPL-Caltech

"Understanding the genesis of these non-biological, carbon-containing macromolecules on Mars is crucial for developing future missions to detect evidence of life," Steele says. — **B. A.**

Black hole blues. **Astronomers learned that as the supermassive black hole in a galaxy's center becomes more energetic, as depicted in this artistically modified image of galaxy Arp 220, its rate of star formation noticeably decreases.** NASA/JPL-Caltech

Hungriest black holes thwart star growth

Deep within the centers of large galaxies lie monsters — supermassive black holes. The most active can devour gas and dust so messily that the infalling material heats up and releases energy. New findings in a *Nature* paper published May 10 show that the most powerful active black holes hinder star formation in their host galaxies.

"We want to know how star formation and black hole activity are linked," says lead author Mathew Page of University College London in England. "The two processes increase together up to a point, but the most energetic black holes appear to turn off star formation."

Astronomers have long suspected that active black holes could have this effect, likely because the energy released by the black holes disturbs and scatters the pools of cold gas required to create stars. They had only scarce evidence of this, however, until Page and his team compared star formation rates and central black hole emissions in 65 galaxies.

For the most part, the team observed a direct correlation between the two. For galaxies with the most active black holes, however, stellar growth quickly dropped off. It will take more research to determine whether this means that the strongest black holes intrinsically hamper star formation or that all galaxies will suffer the same fate — the most active simply accelerate the process. — **B. A.**

Discovery provides new benchmark for brown dwarfs

Understanding a class of objects known as brown dwarfs has challenged astronomers. These substellar bodies are more massive than giant planets but not massive enough to sustain nuclear fusion in their cores, and scientists have had difficulty constraining their properties. But a new discovery, published in the May *Monthly Notices of the Royal Astronomical Society*, could provide a key benchmark in distinguishing these "failed stars" from giant planets.

While combing through data from NASA's Wide-field Infrared Explorer satellite, David Pinfield of the University of Hertfordshire in the United Kingdom and colleagues discovered BD+01 2920B, a brown dwarf some 20 to 50 times as massive as Jupiter composed of more than 99 percent hydrogen and helium and with a temperature of only 760° Fahrenheit (400° Celsius). The brown dwarf orbits a G-type star, the same spectral type as the Sun, which is a more readily characterized object than the red dwarfs scientists frequently find as companions to these "ultra-cool" brown dwarfs.

J. Pinfield for the RoPACS network (Univ. of Hertfordshire)

Brown dwarf benchmark. **The newly discovered brown dwarf BD+01 2920B is depicted in the foreground of this artist's impression with its stellar companion. Because the companion is a common G-type star (the same class as the Sun), astronomers could more readily constrain the brown dwarf's physical characteristics.**

Because its companion allowed the team to better constrain the physical properties of BD+01 2920B, it becomes a benchmark to test cool brown dwarf atmospheres and potentially study the abundances of these ultra-cool objects in the universe. — **KARRI FERRON**

QUICK TAKES

STELLAR SPECTACLE
Astronomers caught the old star WISE J180956.27-330500.2 in the explosive process of throwing off massive amounts of dust, according to a May 20 paper in *The Astrophysical Journal Letters*.

ARSENIC IN OLD PLACE
A May 1 paper in *The Astrophysical Journal* announced arsenic and selenium in a Milky Way star previously thought too old for such elements.

BOLT PREDICTION
A technique to observe Earth's lightning-related signature, known as Schumann Resonance, also can study the signal on other planets, according to a May 1 paper in *The Astrophysical Journal*.

EVOLUTION REVOLUTION
An online paper in *Monthly Notices of the Royal Astronomical Society: Letters* published May 15 determines that some of the oldest galaxies evolved faster than expected, allowing for planets and even life much earlier in the universe's history than thought.

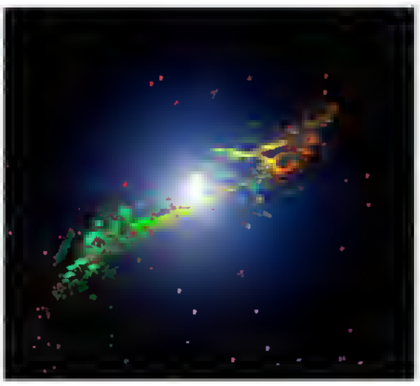
THAR BE YARKOVSKY
Scientists at the May 19 Asteroids, Comets and Meteors 2012 meeting in Niigata, Japan, announced measurements of asteroid 1999 RQ_{36} so precise that they observed the Yarkovsky effect (based on the effects of absorbing and emitting light).

CONGRATS, JCMT
The James Clerk Maxwell Telescope (JCMT) in Hawaii reached its 25th anniversary of observations April 27.

CONDOLENCES, JCMT
The U.K.'s Science and Technology Facilities Council announced May 31 that it would cease support for its Hawaii-based telescopes (including the JCMT) in the next two years.

GIVING GALEX
NASA officially lent its Galaxy Evolution Explorer (GALEX) to the California Institute of Technology on May 14, allowing its mission to continue without government funding.

PUSHY PLANETS
A paper in the May 22 *Proceedings of the National Academy of Sciences* suggests that planetary systems with "hot Jupiter" type planets likely preclude Earth-like worlds from forming. — **B. A.**



ALMA (ESO/NAOJ/NRAO); ESO/Y. Beletsky

Peering past a galaxy's dark dust

Sensitive vision. Centaurus A (NGC 5128), the most prominent radio galaxy in the sky, is well-known for a dark dust band that obscures its center. To peer through the dust requires using longer wavelengths of light, something the new Atacama Large Millimeter/submillimeter Array (ALMA) specializes in. By combining ALMA's 1-millimeter observations with near-infrared ones made with the European Southern Observatory's (ESO) New Technology Telescope, scientists were able to reveal the position and motion of gas clouds in Centaurus A's center. Greener features indicate carbon monoxide gas coming toward ALMA while more orange areas show gas moving away. Such a distribution indicates that the gas is orbiting NGC 5128. ESO released this new image May 31. — **K. F.**

SPACE SCIENCE UPDATE

Historic launch to ISS

At 3:44 A.M. EDT May 22, a rocket launched from Cape Canaveral Air Force Station in Florida. But it wasn't just any launch. Atop Space Exploration Technologies' (SpaceX) Falcon 9 was the unmanned Dragon spacecraft, set to make history. Three days later, on May 25, Dragon became the first craft from a commercial company to attach to the International Space Station (ISS). The reusable craft remained at the ISS for five days and on May 31 splashed down safely in the Pacific Ocean.

After the Falcon 9 launched Dragon into orbit, the craft's sensors and flight systems underwent a series of tests to ensure it could maneuver properly before nearing the ISS. First, its solar arrays deployed, and then the door that covered the craft's sensors opened. This allowed Dragon to test how it measured its movement and later proximity to the ISS.

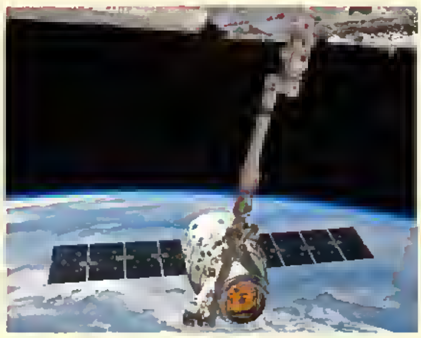
NASA had to give the OK for Dragon to attempt to berth with the ISS; this would wait until the craft underwent additional maneuver tests hundreds of meters from the station. On May 25, Dragon was allowed to approach the ISS.

At 9:56 A.M. EDT, as Dragon came within feet of the station, a robotic arm controlled by ISS astronauts reached out, captured the craft, pulled it toward the space station, and attached it to the complex.

The next morning, ISS crewmembers opened Dragon's hatch — a process that took some two hours. Over the next five days, astronauts unloaded 1,146 pounds (520 kilograms) of food, student experiments, and other cargo from Dragon and filled it with 1,455 pounds (660kg) of hardware and additional items to return to Earth.

On May 30, the robotic arm pulled Dragon away from the ISS and released it for its journey home. Shortly after entering Earth's atmosphere, the spacecraft deployed two sets of parachutes to slow its descent. Dragon splashed down May 31 at 8:42 A.M. PDT (11:42 A.M. EDT) in the Pacific Ocean about 450 miles (720 kilometers) off the coast of Southern California.

This demonstration flight was SpaceX's second under NASA's Commercial Orbital Transportation Services agreement to coordinate crew and cargo transfer to the ISS with commercial companies. Dragon's historic approach and berth show that the private sector can, and will, contribute heavily to future space exploration. — **LIZ KRUESI**



NASA

Connection made. Crewmembers use the International Space Station's (ISS) robotic arm to grapple the Dragon spacecraft and attach it to the station on May 25. On this day, Dragon became the first craft designed by a commercial company to berth with the ISS.

FAST STAT

12.7 BILLION

The distance, in light-years, to the most distant protocluster of galaxies ever found, according to a May 10 paper in *The Astrophysical Journal.*

Disappearing world. The Kepler telescope caught the signature of a possible disintegrating planet passing in front of its star, shown in this artist's conception. NASA/JPL-Caltech

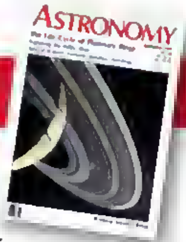
Found: a star that vaporizes its world

The Kepler space telescope continuously stares at some 170,000 stars, looking for dips in light. A regular drop in a star's luminosity could suggest that this sun hosts a planet that crosses its face from Kepler's viewpoint. The telescope has found thousands of candidate planets with this method. Researchers then take follow-up observations and studies to determine if the candidate planets are exoworlds or something else. Occasionally, the Kepler data holds surprising planetary systems.

One team analyzing observations and performing computer simulations describes an odd light pattern they think comes from a disintegrating planet in the June 10 issue of *The Astrophysical Journal*. They found that the light from the orange star KIC 12557548 dropped by various amounts every 15.685 hours. This observation suggests that something blocks the star regularly, but by different amounts. Saul Rappaport of the Massachusetts Institute of Technology in Cambridge and colleagues determined that a binary planet system passing in front of the star could not produce the observations. Instead, they calculated that the star likely hosts a small planet that is disintegrating from close proximity to its sun. A tail of dust follows the world, and this material blocks light from the star, causing the odd pattern.

The scientists estimate that this possible planet is at most twice Mercury's mass and orbits so close to its star that its surface temperature is a searing 3300° Fahrenheit (1820° Celsius). KIC 12557548 vaporizes the world's dust and gas, and according to calculations, the planet will fully disintegrate in 100 to 200 million years. — **L. K.**

25 years ago in *Astronomy*

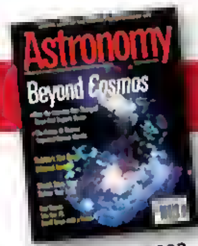


September 1987

In the September 1987 issue, Donald Frederick Robertson outlined an ambitious plan for studying Saturn and its biggest moon in "Cassini," named for the planned orbiter. The mission faced uncertainty, but space research won out.

On July 1, 2004, Cassini flew through Saturn's rings and entered orbit, and in January 2005, the Huygens probe descended through the mists of Titan's atmosphere.

10 years ago in *Astronomy*



September 2002

The September 2002 issue featured a look back at seminal science programming in "Beyond *Cosmos*." Some two decades after the premiere of Carl Sagan's PBS show, then Managing Editor David J. Eicher fondly recalled Sagan's influence in science education. "He arrived like an alien visitor from the world of academia," Eicher wrote. "Carl Sagan, astronomy professor from Cornell, had begun to change science forever." — **B. A.**

Volcano voyage The European Space Agency announced April 26 that Mars Express data analyzing volcanic regions reveal that the planet's outermost layer varies in thickness.

Southwest Research Institute

Astroconfidential by Karri Ferron

Why study our solar system's boundary?

David J. McComas

Principal investigator for NASA's IBEX mission, Southwest Research Institute, San Antonio, Texas

The Interstellar Boundary Explorer (IBEX) mission gives us the chance to investigate one of the last unexplored frontiers of our solar system — the boundaries where our Sun's neighborhood ends and the rest of the galaxy begins. The focus of the mission is to understand what causes these boundaries, how they change over time, and what they mean for the future exploration of the solar system and beyond.

In our solar system, the Sun emits a "wind" of material. As the solar wind streams away from the Sun, it races out toward the space between the stars called the "interstellar medium." The solar wind blows against the ionized gas and clears out a cavity-like region — the heliosphere.

Our heliosphere is like a protective cocoon being inflated in the interstellar medium by the solar wind. As our Sun orbits the center of the galaxy every couple hundred million years, it bobs in and out of the disk of the galaxy like a horse on a merry-go-round. As it does, it passes through areas of the interstellar medium with different speeds and densities, causing the heliosphere to change in shape and size.

Understanding how the interstellar medium affects the heliosphere is important to learning how it protects us. For one, it is a crucial layer of defense against dangerous cosmic rays. As these charged particles try to enter our solar system, the heliosphere deflects most of them. Earth's magnetic field is then usually able to shield us from the remaining cosmic rays. However, astronauts on deep-space missions cannot take Earth's protection with them, so we must learn how and to what extent the heliosphere can shield them.

Fundamentally, however, the IBEX team and I are excited to study these boundaries because they have been so surprising. Observations show just how little we understand the outer reaches of the heliosphere. From the unanticipated IBEX Ribbon to the "breeze" of newly detected incoming interstellar neutral particles and the lack of a bow shock in front of the heliosphere (see page 19), there have been discoveries everywhere we turn, and we are looking forward to learning more!

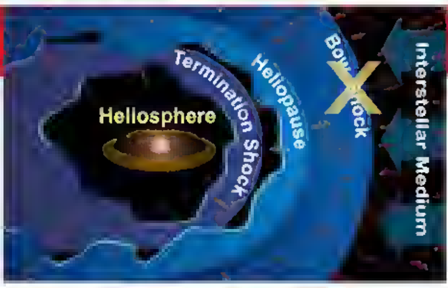
BRIEFCASE

Asteroid family tree

Scientists with NASA's Dawn mission that is exploring Vesta have aged the asteroid's huge crater: Rheasilvia was created in a collision that occurred about 1 billion years ago. This is much more recent than expected. The team also reports in the May 11 issue of *Science* that the amount of material excavated by the impact suggests that most of the observed asteroids and meteorites with Vesta's composition were formed in this specific collision. — L. K.

Scope's dual location

The Square Kilometre Array project took a big step forward May 25 when scientists announced that they had selected a dual location for what will be the world's largest and most sensitive radio telescope. Mid-frequency aperture arrays will be built in Southern Africa while low-frequency aperture arrays will be placed in Australia. Construction should begin in 2016. — L. K.



Less pressure. New data from NASA's Interstellar Boundary Explorer combined with discoveries from the Voyager probes suggest that the Sun doesn't move fast enough through the galaxy, and thus isn't creating enough pressure, to form a bow shock. Southwest Research Institute

The century's last Venus transit

NASA/SDO, AIA

Rare spectacle. Observers and telescopes across Earth, and satellites orbiting it, witnessed Venus cross the Sun's disk June 5/6. This rare transit last occurred June 2004 and won't happen again until December 2117. On June 6, researchers with NASA's Solar Dynamics Observatory released this image montage showing Venus' path across our star. Intense magnetic activity on the solar surface is also apparent at the bottom of this photo. — L. K.

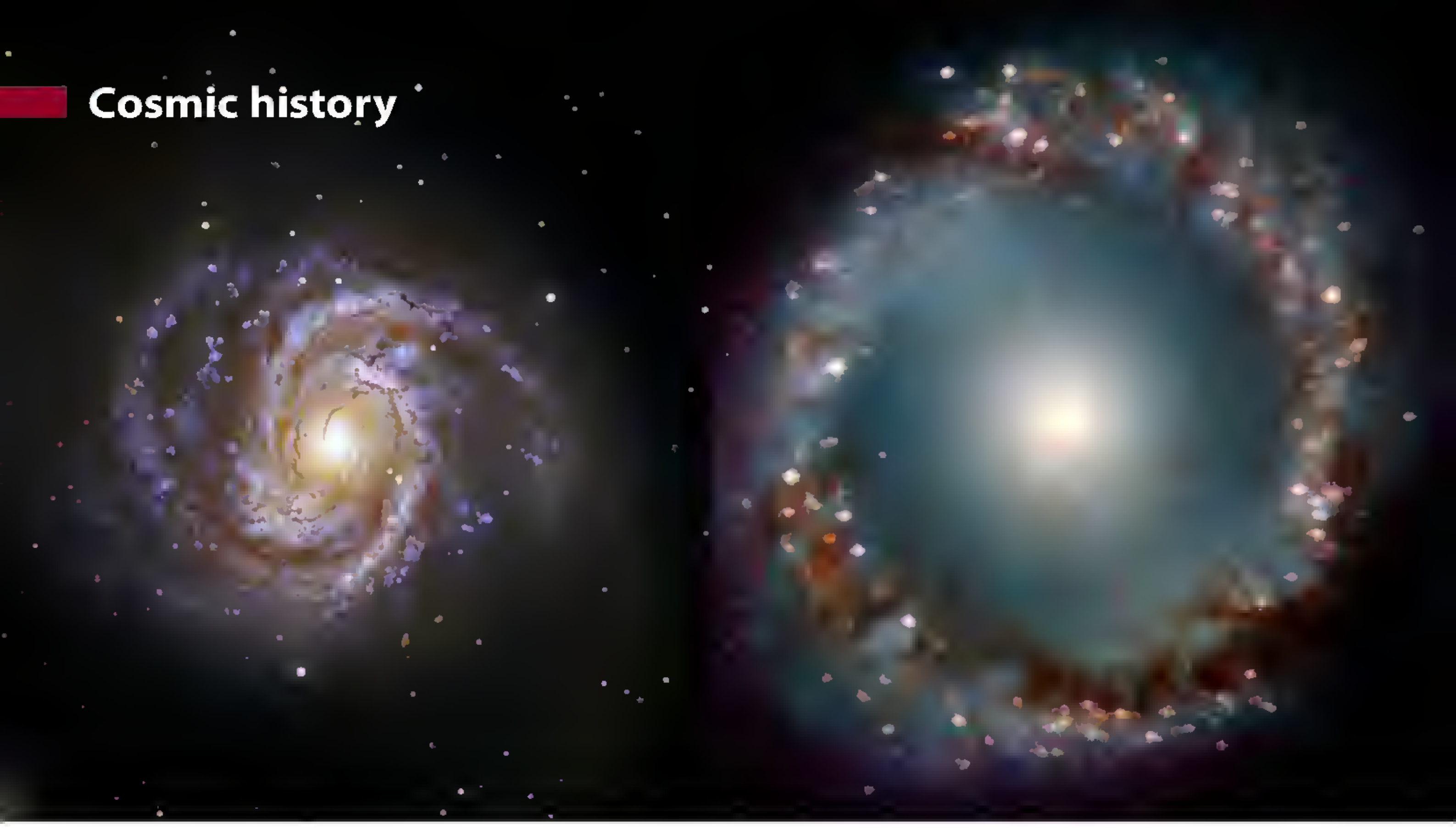
The solar system's "softer" edge

For decades, scientists thought the Sun's wind of charged particles in addition to the solar magnetic field create three distinct boundary layers between the Sun and the rest of the galaxy; these collectively are called the heliosphere. By combining recent data from the twin Voyager probes and NASA's Interstellar Boundary Explorer (IBEX), though, astronomers have determined that the Sun doesn't plow through the galaxy fast enough to create the expected outermost boundary. The results appeared online May 10 in *Science* Express.

Voyager 1 and 2 have confirmed that the first boundary layer (the termination shock) exists, as they both passed through it years ago; this is where the solar wind slows to speeds below supersonic. Both craft have also seen evidence of the second layer — the heliopause — as they near it; at this layer, the inward pressure from the galaxy's material balances the solar wind's pressure.

Scientists predicted a third layer — the bow shock — that arises from the Sun's protective magnetic bubble ramming into galactic material and thus slowing it. (A familiar example of a bow shock is when a supersonic jet compresses and pushes air aside.) IBEX measurements earlier this year showed that the Sun is moving about 7,000 mph (11,300 km/hour) slower than the expected 59,000 mph (95,000 km/h). "That might not seem like a huge difference, but it translates to a quarter less pressure exerted on the boundaries of the heliosphere," says IBEX principal investigator David McComas of the Southwest Research Institute in San Antonio, Texas (see more from McComas on page 18). "There's a very different interaction, a much weaker interaction, than previously thought."

Scientists say that instead of a bow shock, the third layer is more like a "bow wave," and thus the Sun's wind and magnetic field create a gentler compression as our star moves through the galaxy. — L. K.



Quest for the **most**

The search for the first structures in the universe has baffled astronomers

If the universe were ageless — if it had always looked exactly as it appears today — then gazing deeper into space would offer no new insights. We would see galaxies forever and ever. But the discovery that the universe began as a Big Bang altered our understanding of the link between time and distance. Astronomers know that the universe in the past appeared quite different from the universe today. The cosmos, scientists learned, has evolved.

Scientists have known for more than 300 years that light travels at a finite (although tremendous) speed, since Danish astronomer Ole Rømer's studies of Jupiter in 1676.

Adam Frank *is a member of* Astronomy's *Editorial Advisory Board and a professor of physics and astronomy at the University of Rochester in New York.*

This recognition of inseparable links between space, time, and light is thus encoded in one of astronomy's basic measures: the "light-year," or the 5.88-trillion-mile (9.46 trillion kilometers) distance that a beam of light travels in one year. This means that galaxies that lie 1 million light-years distant appear to earthbound observers as they existed 1 million years in the past. To look out into space is to see back into different epochs of cosmic history. Look back far enough, and you could glimpse the beginning.

That was how the race to see the moment when the universe started forming structures — the quest to see the most distant objects — began.

Astronomers aim to observe the moment when primordial gas transformed into large-scale objects like stars and galaxies. And although astronomers have been searching for the most distant (and thus, most ancient) objects for more than four decades, a new generation of telescopes promises glimpses of the era when starlight first filled the night.

Back to the beginning

As is often the case in astronomy, the quest began without scientists realizing just what they had stumbled upon. "The story starts around the late 1950s with quasars, or 'quasi-stellar objects,'" says Avi Loeb, a professor of astrophysics at Harvard University in Cambridge, Massachusetts, and an expert on the early epochs of cosmic evolution.

Each chemical element emits radiation at specific wavelengths. Astronomers use these elemental fingerprints to bin stars into different categories. Some stars, for example,

ESO/IDA/Danish 1.5 m/R. Gendler, J.-E. Ovaldsen, C. C. Thöne, and C. Féron (M100); ESO (NGC 1097 and close-up); NASA/ESA/The Hubble Heritage Team (STScI/AURA) (NGC 5866)

distant objects

by Adam Frank

for decades. But telescopes now on the horizon promise to shed new light.

▲ **Whereas most modern-day galaxies** contain billions of stars and display elegant structure, the earliest galaxies were smaller clumps of primordial material. For decades, astronomers have been searching for the most distant objects, and the current record-holder is a galaxy whose light has been traveling toward us for 13.2 billion years.

may show strong fingerprints of hydrogen while others show the signature of helium or calcium. Quasars appeared as point sources — like stars — but astronomers couldn't trace the patterns in their spectra to any known element. Because these objects looked like stars, scientists called them quasi-stellar objects. The fingerprints were "unlike anything seen before," says Loeb. Were quasars telling astronomers that elements existed in space that did not exist on Earth? Their real identities didn't come to light until the early 1960s.

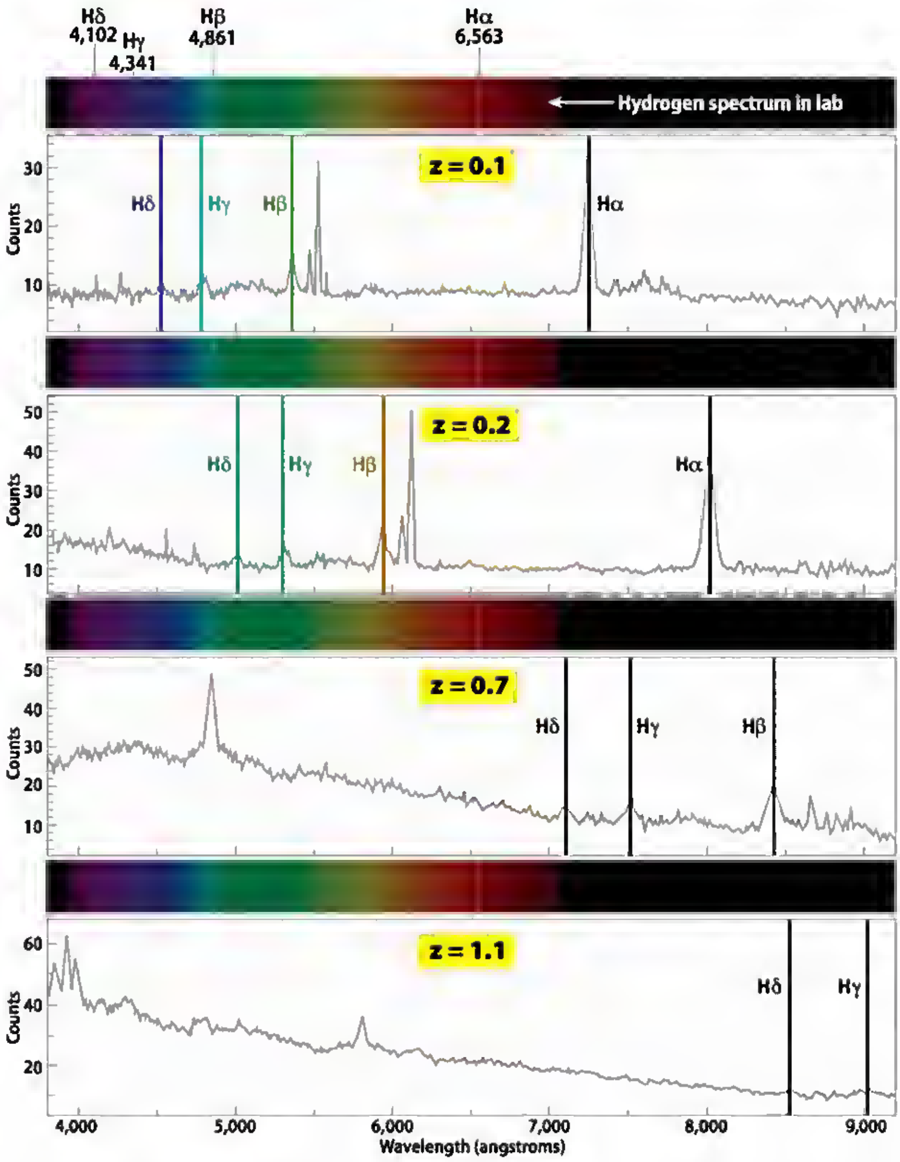
Then, Maarten Schmidt of the California Institute of Technology in Pasadena solved the puzzle of what was happening with the spectrum from one of the first of these discovered objects, 3C 273. Schmidt saw that the strange patterns in light were really nothing more than the spectra of common hydrogen shunted drastically to longer wavelengths. Quasars, Schmidt realized, were highly "redshifted."

If an object is moving toward an observer, its light shifts to shorter (more blue) wavelengths; if the object instead is moving away from the observer, its light shifts toward longer (redder) wavelengths. Like the change in tone (and wavelength) of a passing ambulance's siren, 3C 273's spectrum meant it was moving away from Earth. More importantly, its recession speed was higher than anything detected before.

Cosmologists measure distance in terms of redshift (called z), which increases the further back in time and space they explore. But redshift doesn't march in linear fashion with time. Instead, it starts small and heads toward infinity as one gets closer to the universe's moment of creation — the Big Bang. A redshift of 1 corresponds to a distance of about 7.5 billion light-years when the object emitted that light. (The universe's expansion has since moved the object farther away and stretched the wavelength even more.) A redshift of 10 marks a distance of roughly 13 billion light-years.

When Schmidt calculated 3C 273's velocity from its redshift, he found that the quasar

Laboratory value vs. redshift



The characteristic light signature — called a spectrum — of a quasar tells astronomers its redshift, how far away it is, and how fast it is moving. Objects farther from Earth are receding faster. Researchers compare a quasar's spectrum to laboratory light signatures (for example, hydrogen in this diagram) to determine this information. *Astronomy*: Roen Kelly, after Mark Subbarao (University of Chicago)/Astrophysical Research Consortium/SDSS

was receding at 29,000 miles per second (47,000 km/s) — 15.8 percent of the speed of light. That movement is due to the fact that everything on cosmic scales is expanding away from everything else; astronomer Edwin Hubble discovered this in 1929.

Using what's called the Hubble law, Schmidt's quasar could be placed at roughly 2 billion light-years away from Earth. His colleagues at the same time discovered that the quasar 3C 48 has a redshift of 0.3675, placing the object at some 4 billion light-years from Earth when it emitted its light. This colossal distance made it the farthest object ever observed. The discovery started astronomers racing into the depths of time and space as they were driven to ask if there are even farther objects.

With such enormous distances, quasars became more than just an astronomical curiosity; they became beacons for the science of cosmology.

Heading into the dark

In the mid-1960s, scientists stumbled across an odd all-sky signal. No matter what direction they pointed their radio antenna, they saw microwave radiation. Astronomers soon recognized that this microwave background was light emitted a mere 380,000 years after the moment that the universe came into existence, at redshift 1,100. Before this time, in the earliest epochs of cosmic history, the universe was a roiling, superhot, superdense "plasma" of particles and light photons.

As the universe expanded and cooled, particles collided and sometimes formed new, stable combinations. When temperatures dropped enough, electrons and protons could join to form the first hydrogen atoms. Before this combination into atomic hydrogen, photons had been closely tied to electrons and protons, and continually collided and scattered off the particles. Once the temperature cooled enough, the photons could stream away with far fewer collisions.

Scientists say that this was the moment when the universe became "transparent" to the photons. Since then, cosmic expansion has redshifted the released photons, which had infrared wavelengths at the time, into the microwave regime — it's called the cosmic microwave background (CMB) radiation. The photons travel from one end of the cosmos to the other without interacting as often with matter. That is why astronomers still can see them flowing toward Earth from every direction.

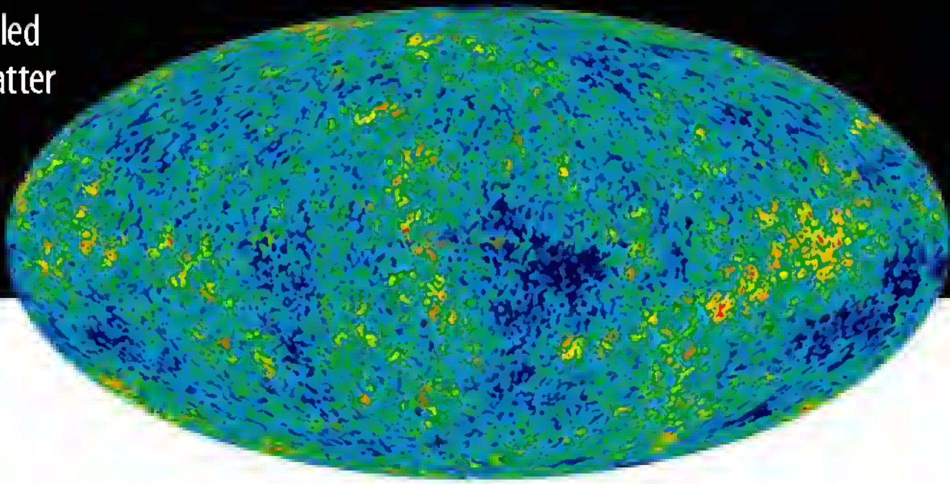
While the universe may have become transparent to the CMB photons, other wavelengths of radiation suddenly found their way barred. Atomic hydrogen is good at absorbing visual-wavelength photons. In a universe full of atomic hydrogen, any light emitted in these bands is quickly absorbed. Thus, when protons and electrons combined into hydrogen atoms 380,000 years after the Big Bang, it was also the beginning of what astronomers call the cosmic Dark Ages. In the search to learn the universe's history, the CMB and these Dark Ages would remain closely paired.

Quasars' true nature

"The CMB told us the universe began as an ultradense, ultrahot soup of particles," says Loeb. "That was 13.7 billion years ago. But today we see galaxies and stars and lots of empty space between them. How did we get from there to here?" Quasars are a stepping-stone to understand that question.

The first discovered quasars were some 2 and 4 billion light-years away, with redshifts of 0.158 and 0.3675, respectively. "While that was a big deal when they were discovered," says Loeb, "we've now pushed much farther back toward the beginning of structure formation and learned so much more

In the mid-1960s, scientists stumbled across an odd all-sky signal. No matter what direction they pointed their radio antenna, they saw microwave radiation.



The cosmic microwave background displays the beginning of structure in the universe. The color differences indicate density fluctuations of just a few parts in 100,000 — these evolved into galaxy clusters and voids through cosmic history. NASA/WMAP Science Team

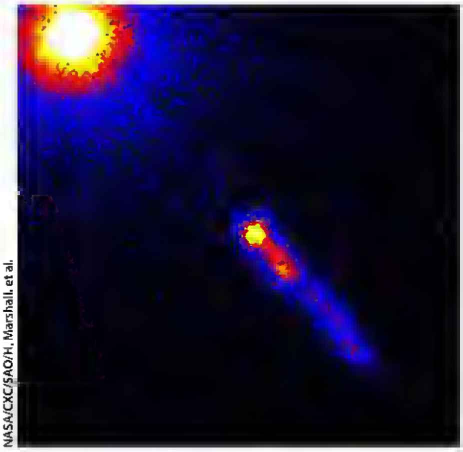
in the process." Ironically, one of those lessons is that quasars are not the best way to explore the early epoch of structure formation in the universe. "They were not the first thing created in cosmic history," says Loeb.

By the 1980s, astronomers understood that a quasar was nothing more than the central region of a galaxy containing a massive, hungry black hole. Quasars act as cosmic beacons because those billion-solar-mass black holes pull in vast quantities of gas, which heats up and glows intensely on its way down into the object (only once it crosses the black hole's "event horizon" boundary does the light become trapped). That tremendous light output is why quasars can serve as bright beacons visible across vast stretches of space.

But these massive black holes require time to be assembled. The earliest quasar astronomers have discovered is at z=7.085, or 770 million years into the universe's history. "That means there are not many quasars early in cosmic history," says Loeb.

The earliest structures

This paucity of super-high-redshift quasars comes as no surprise to Loeb and other



NASA/CXC/SAO/H. Marshall, et al.

The first redshift that scientists identified belongs to 3C 273 (which emits a high-speed jet seen in this X-ray image). This quasar is the closest to Earth, about 2 billion light-years away, but it was the second most distant object known when astronomers learned its identity in 1963.

theorists. In their models of cosmic history, structure starts small and builds its way up. That is why the Holy Grail of high-redshift objects is no longer the first quasars — it's the first galaxies and stars.

"We have a standard cosmological model," says Loeb, referring to the precision with which astronomers now know the fundamental parameters governing cosmic evolution. "That wasn't the case a couple of decades ago."

Cosmologists know that the universe isn't just the material they can directly observe. It also contains mysterious dark matter, which doesn't interact via radiation, so scientists can't see it. The precision cosmology of today lets astronomers know the exact mix of dark and normal matter that the universe began with. And "just as important," says Loeb, "from the CMB, we have a really good understanding of the density perturbations that existed early on in the cosmic gas."

The perturbations Loeb refers to are tiny lumps, or overdense regions, in the soup of particles that emerged after the Big Bang. After the release of the CMB photons, the universe was able to cool to the point where the gravitational force of these lumps could begin working its magic. "The CMB tells us exactly what the initial perturbations in the universe looked like," says Loeb. "From there, we can calculate what happened next as gravity began pulling more and more material into the overdense regions."

How to grow a universe

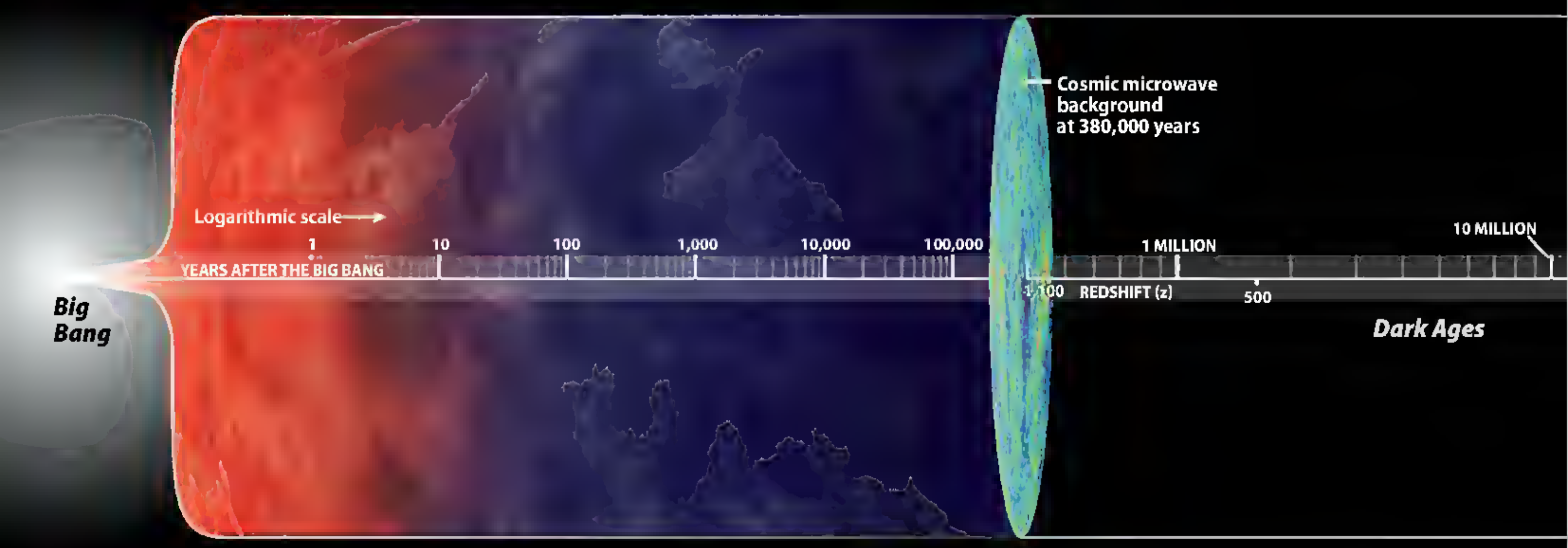
At around 100 million years after the Big Bang (a redshift of about 30), lumps that were just one part in 100,000 times more dense then their surroundings during the CMB's formation grew into light-year-wide clouds of hydrogen gas. From their calculations, astronomers believe these early clouds contained hundreds of thousands of solar masses — equivalent to the size of globular clusters today. But unlike the gas floating through space in our modern cosmic epoch, these clouds contained no elements more complex than helium and a bit of lithium.

"The elements that make up our bodies are created inside stars through nuclear fusion," says Loeb. "The first generation of stars wouldn't have any of those elements." In modern star-forming regions, light emitted by elements like carbon and oxygen acts as a refrigerant. As light leaves the gas, the clouds can cool down and collapse under their own gravity. In the absence of these elements, the early clouds remained relatively warm. "With no heavy elements, the clouds tended to fragment into pretty massive clumps," says Loeb, "so the first population of stars were themselves pretty massive."

While most of the largest stars in the universe today hover around 100 times the mass of the Sun, the first stars to form likely were monsters weighing in at 300 or 400 solar masses. This era of giants didn't last long, however. "As soon as the first supernova exploded, heavy elements made in the heart of these massive stars got disbursed into the surrounding medium," says Loeb.

After that, cooling became more effective. The next generation of star-forming clouds could both lower their temperatures and fragment more easily to begin

The quest to reach the beginning



The universe began as a dense, hot point and has evolved into giant structures over 13.7 billion years. Scientists are searching for the time when the first protogalaxies and stars formed — a few hundred million years after the Big Bang. So far, they've discovered a galaxy that existed 480 million years after the universe began, but they expect even earlier objects. (The timescale of this illustration changes after the cosmic microwave background.)

The search ramps up

Name	Year published	Redshift	Years after Big Bang
3C 295	1960	0.461	8.9 billion
3C 9	1965	2.018	3.3 billion
QSO B1442+101	1974	3.53	1.8 billion
QSO J0048-2903	1987	4.01	1.6 billion
CL 1358+62 G1 and CL 1358+62 G2	1997	4.92	1.2 billion
SN 1997ap (type Ia)	1998	0.83	6.7 billion
SDSS 1030+0524	2001	6.28	900 million
SN 19941 (type IIn)	2009	2.357	2.8 billion
UDFy-38135539	2010	8.56	600 million
ULAS J1120+0641	2011	7.085	770 million
CL J1449+0856	2011	2.07	3.2 billion
GRB 0904298	2011	9.4	520 million
UDFj-39546284	2011	10	480 million
SN Primo (type Ia)	2012	1.55	4.2 billion

KEY: galaxy; galaxy cluster; gamma-ray burst; quasar; supernova

forming smaller stars — the kind we are familiar with today. "This happens around a redshift of 20 to redshift 10," says Loeb. "It's also during this epoch that the first true galaxies are forming."

The dispersal of heavy elements allowed larger conglomerations of gas to collect, including early protogalaxies. Simulations of cosmic evolution show vast clouds forming with masses of a billion or 100 million Suns during this epoch — about the size of the Milky Way's dwarf satellite galaxies. "The gas cools down to about 10,000 degrees, and that is when you get to see lots of star formation beginning to occur," says Loeb. It is somewhere around this time that the Dark Ages began to lift.

Moving into the light

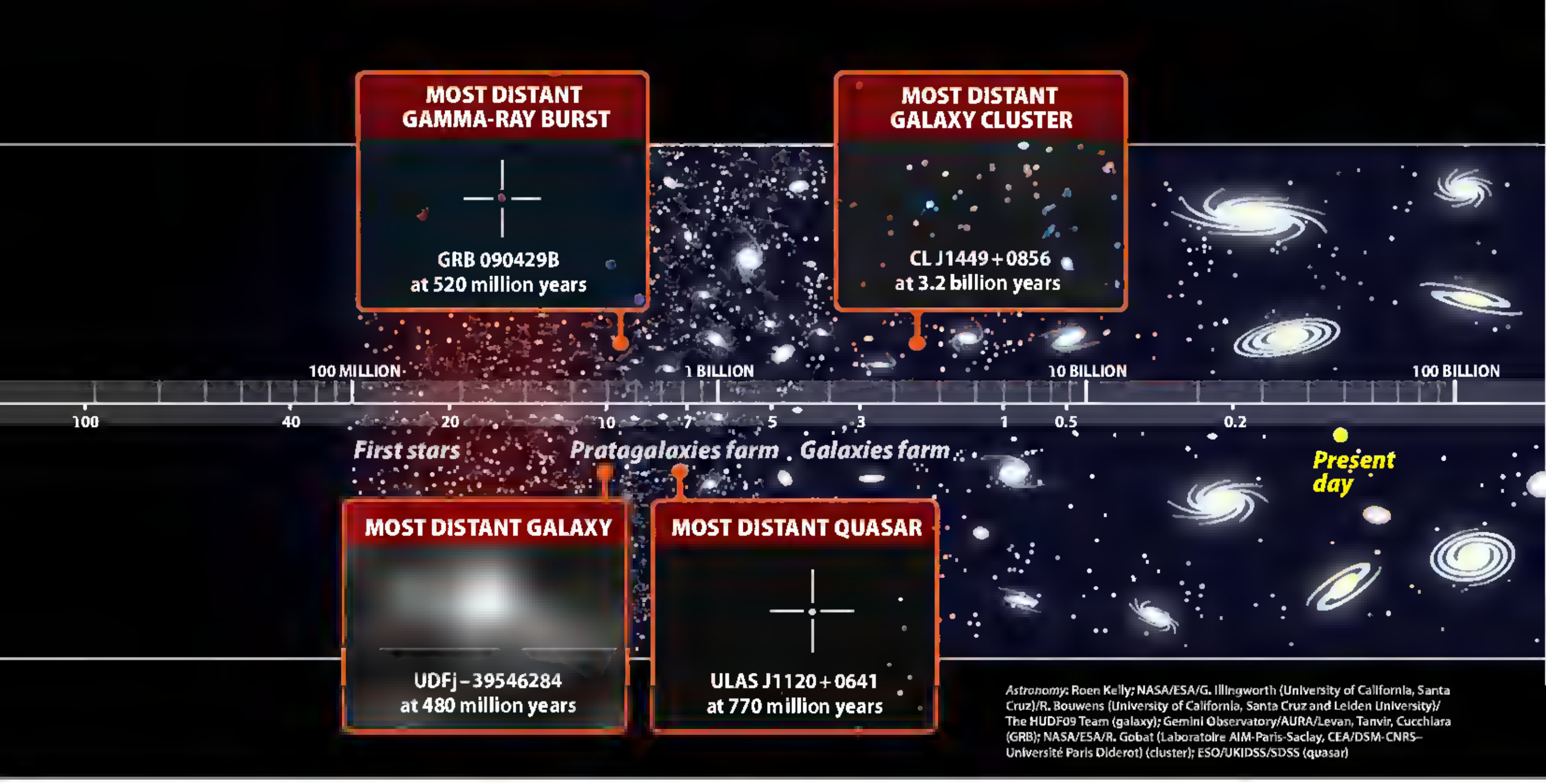
The initiation of large-scale star formation is a key moment in the history of the universe. Stars produce a lot of ultraviolet (UV) radiation, which can rip electrons off hydrogen atoms to create hydrogen ions. With enough UV light, such as that from the first generation of stars, the universe turns back into free protons and electrons. "Once the galaxies start forming lots of stars, they become ionization factories," says Loeb. Hydrogen ions don't absorb visible light, so astronomers can collect it across great distances.

The epoch of reionization ends at around redshift 7, or about 780 million years after the Big Bang. Seeing into this reionization era — the end of the Dark Ages — marks the frontier of today's high-redshift race. "These are the really important missing pages in the photo album of cosmic history," says Loeb. "We can see galaxies like the Milky Way forming all the way from 1 billion years after the Big Bang until the present time. But we don't see the beginning of the story." Using a new generation of tools that should come online in the next decade, astronomers like Loeb hope to shed some light on the universe's Dark Ages.

Seeing into the unknown

Astronomers plan to attack the problem of moving to (and beyond) the first billion years in a number of ways. For one, "you can try and actually observe the neutral hydrogen gas that makes the universe dark," says Loeb. That strategy requires moving to lower frequencies of light, which translates into longer wavelengths. Neutral hydrogen naturally emits photons with a wavelength of 21 centimeters, and those that start at the distance of the cosmic Dark Ages stretch to even longer wavelengths constituting low-frequency radio waves. "There are projects like the Low Frequency Array in Europe trying to make these observations," says Loeb. "The whole field is just getting started, but it's going to be very exciting."

The infrared-observing James Webb Space Telescope (JWST), slated for launch in 2018, was specifically designed to see the early phases of galaxy formation. Optical

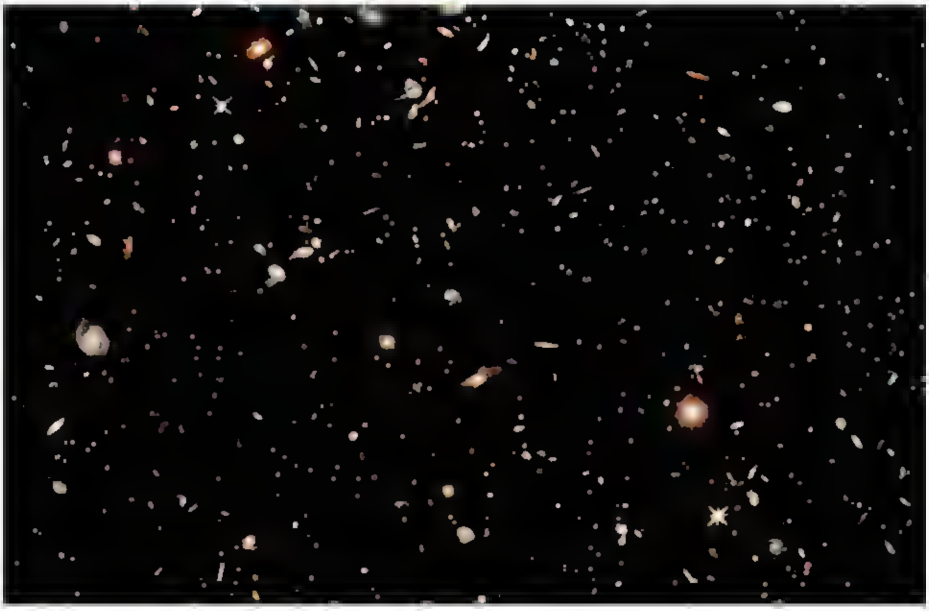


Astronomy: Roen Kelly; NASA/ESA/G. Illingworth (University of California, Santa Cruz)/R. Bouwens (University of California, Santa Cruz and Leiden University)/The HUDF09 Team (galaxy); Gemini Observatory/AURA/Levan, Tanvir, Cucchiara (GRB); NASA/ESA/R. Gobat (Laboratoire AIM-Paris-Saclay, CEA/DSM-CNRS–Université Paris Diderot) (cluster); ESO/UKIDSS/SDSS (quasar)

light emitted by these distant young galaxies will have been highly redshifted into the infrared. "JWST should, in principle, be able to detect galaxies out to redshifts of 10 or 12," says Loeb. This equates to 480 to 350 million years after the Big Bang.

To get even further, a new generation of monstrously large telescopes is in the planning stages. The first objects to form are so far away that they'll appear exceedingly dim and hard to observe. Only extremely large telescopes have any hope of seeing them.

Groups in the United States are planning two of these huge instruments: The 24.5-meter Giant Magellan Telescope will observe the southern skies from Chile while the Thirty Meter Telescope will scan the Northern Hemisphere atop Mauna Kea in Hawaii. The Europeans are also planning the 39.3-meter-wide European Extremely Large Telescope for Chile. Together, all three instruments will have much greater sensitivity to extremely distant and dim objects than anything available today. In large part, the high-redshift race is what's pushing these projects forward.



The Hubble Ultra Deep Field has allowed astronomers to discover galaxies at redshift 8 and even 10, marking the most distant galaxy found yet. To create the composite image, scientists used the Hubble Space Telescope to stare at a seemingly "empty" area of space for 48 hours in three near-infrared wavelength bands. NASA/ESA/G. Illingworth and R. Bouwens (University of California, Santa Cruz)/The HUDF09 Team

Hoping for the unexpected

For all his theorizing about the formation of structure in the universe, Loeb is hopeful that these upcoming huge telescopes will discover something no one expected. "While I would love to see our theories confirmed, I would be even happier if observers find results that are not in line with our theoretical expectations," says Loeb. "If they find exactly what we expected, it would be kind of boring. I mean, it will be good to claim we predicted it all, but it would really be nice to see some new physics we did not anticipate."

That, of course, is the beauty of science. Somehow, 13 billion years or so ago, the universe began creating structures. Today, you and I are direct consequences of that dark epoch when the first stars and galaxies formed. Now astronomers who have struggled for decades to see into that darkness are poised to get the first good glimpse of this hidden age of the cosmic story. If scientific history is a good gauge, then Loeb will not be disappointed, and the race will end with more surprises and more questions.

Visit www.Astronomy.com/toc to learn more about the search for the first structures using radio telescopes.

Brian May plays "God Save the Queen" from the roof of Buckingham Palace to commemorate Queen Elizabeth II's Golden Jubilee on June 3, 2002.
© 2002 Arthur Edwards

A life in science and music

You know him best as guitarist, singer, and songwriter from the rock group Queen, but Brian May is also a Ph.D. astronomer, popularizer of the cosmos, stereophotography enthusiast, and advocate for animal rights.

by David J. Eicher

As a teenager, Brian Harold May was shy, uncertain, insecure. "I used to think, 'My God, I don't know what to do, I don't know what to wear, I don't know who I am,'" he says. For a kid who didn't know who he was or what he wanted, he had quite a future in store. Deep, abiding interests and worldwide success would come on several levels, from both science and music. Like all teenagers beset by angst, it was just a matter of sorting it all out.

Skiffle, stars, and 3-D

A postwar baby, Brian May was born July 19, 1947. In his boyhood home on Walsham Road in Feltham on the western side of London, England, he was an only child, the offspring of Harold, an electronics engineer and senior draftsman at the Ministry of Aviation, and Ruth. (Harold had served as a radio operator during World War II.) The seeds for all of May's enduring interests came early: At age 6, Brian learned a few chords on the ukulele from his father, who was a music enthusiast. A year later, he awoke one morning to find a "Spanish guitar hanging off the end of my bed." At age 7, he commenced piano lessons and began playing guitar with enthusiasm, and his father's engineering genius came in handy to fix up and repair equipment, as the family had what some called a modest income. "We were very, very poor," says May.

As he explored music, Brian also discovered scientific pursuits at school. "In the school library, there was this little book called *The Earth*," he says. "It was written by the man who is now Sir Patrick Moore, who has become a good friend in recent times. It had a picture of Earth on the cover and gave a history of Earth from its formation all the way through the beginnings of life, and I was just enthralled. I read it from cover to cover again and again."

The discovery of Moore, England's famous astronomy television presenter, led to Brian staying up late to watch Moore's show, *The Sky at Night*, on the BBC. "I begged my parents to stay up far enough into the night," he says, "and I just became captivated by the whole story of the universe. It's been a lifelong passion, something that's never left me. There's always a part of me who just likes to go out and gaze up at the heavens if I'm fortunate enough to have a clear sky."

David J. Eicher *is editor of* Astronomy. *He has been a Queen fan since his early teenage years, and enjoys being in the same group of fans of both music and astronomy as Brian May.*

▲ **Brian May, age 15,** plays the newly constructed guitar — built by him and his father — dubbed, the "Red Special," London, 1963. (His companion is the family cat, Squeaky.) Harold May/Brian May Archive

◀ **Brian May's 1967 band, 1984,** included (left to right) schoolmate Tim Staffell, Dave Dilloway, Richard Thompson, John Garnham, and May. Brian May Archive

One night in 1955, Harold May brought home a Lonnie Donegan record and shared it with his son. This was in the midst of the skiffle craze of the mid-1950s, when homemade instruments and American blues, folk, and pop coalesced with a new generation of British kids turning on to the new music. "I used to lie under the bed covers with my little crystal set listening to Radio Luxembourg and all this stuff that seemed very exciting and dangerous and forbidden," he says.

May excelled in school, and he readily says, "I had a lot of application, and I liked achieving." His was an intellect that was mathematical, ordered, and also quite creative. Astronomy and music each found a comfortable home here. He entertained his parents by writing a monologue about the stars and speaking it over a playing of "Saturn, the Bringer of Old Age" from Gustav Holst's *The Planets*. A collector, he acquired toys, comics, matchboxes, and before long a camera and telescope, the latter homebuilt. The scope, which he still has, is a 4-inch reflector.

"It was just a kit we bought at Tottenham Court Road," he says, "which was famous for bits of recycled stuff, ex-government lenses, and electrical bits and pieces. Me and my dad used to go down there and find things, and we located a kit for making a telescope that must have cost 10 pounds, I don't know, and we made it together. It's a small scope, but it still gives me pleasure because even though I have a bigger telescope now, the 4-incher can be wheeled out in 10 seconds flat if there's something interesting in the sky."

Another interest emerged to coexist with astronomy and music. All May had to do to acquire this fixation was to sit down as a kid to breakfast. Weetabix, compressed wheat in the form of a biscuit, is served with milk at many an English table. "It was a big thing when I was a kid," says May, "and when you got your packet of Weetabix in those days, you would get a free card inside. An incentive for kids to badger their mums to buy it!"

The card inside was a photographic stereo card. Stereoscopy (stereoscopic, or 3-D, imaging) was invented by Sir Charles Wheatstone in England in 1838. The technique employs two nearly identical images made from a slightly different angle that, when combined by viewing through a special device, appear to merge together to produce a three-dimensional scene. The process was huge in the United States during and after the Civil War era, and was still a novelty of sorts in the Great Depression era when kids could drop a penny in the grocery store stereoscope to see the wonders of the world in 3-D.

The 3-D imagery produced by stereoscopy was a delight to the young May. "Suddenly, these two little flat pictures became one in-depth view of whatever it was," he says, "an animal or a city or a car, and to me this was just magic. I thought, 'If people can do this with photography, why don't they do it all the time?'" And May had always been fond of animals — yet another passion that would rise up throughout his later life.

Enter the Red Special

As May began his teenage years, he continued to play guitar, borrowing one here and there, a friend's Fender Telecaster or Gibson SG. His talent was expanding by leaps and bounds, and he had no instrument of his own, unable to afford one. By the spring of 1963, when May was 15, he and his father decided to build their own guitar. Designing and building an electric guitar from scratch was no easy undertaking, although Harold's engineering background and Brian's methodical, mathematical mind helped the process along. The project comprised 18 months, producing one of the most famous guitars in the history of rock 'n' roll.

Nothing like this instrument existed, and it conspired to give May a unique tone in playing pop music. The guitar's body is made from oak, the neck from an

▲ **The zodiacal light** photographed by Brian May in 1971 from the newly created Observatorio del Teide, Tenerife, Canary Islands. Brian May Archive

◀ **Tenerife Observatory** in the Canary Islands saw Brian May working in 1971 on his coelostat, a flat-mirror instrument that tracks the sky. Brian May Archive

18th-century mahogany fireplace mantle, the fret markers from mother-of-pearl buttons taken from Ruth May's sewing box, and the valve springs used to balance the string tension were salvaged from a 1928 motorcycle. The Mays produced a carefully considered instrument, and after varnishing in deep red mahogany, the guitar took on the name "Red Special."

The guitar's clean tone also came from the Vox AC30 amplifier, and Irish rocker Rory Gallagher showed May how to set it up and drive it to achieve that tone. Another part of the equation was a treble booster, which, as May says, "drives the amp into smooth distortion as it gets rid of a little of the low end." Couple that with Burns' pickups that May installed into the Red Special, and you came out with a unique sound in rock 'n' roll.

"It's a small scope, but it still gives me pleasure ... the 4-incher can be wheeled out in 10 seconds flat if there's something interesting in the sky."

Another part of May's approach was the unusual habit of using a British sixpence coin as a pick. "I discovered the old sixpence coin, which had a reeded edge, and found that if I held it parallel to the strings, it would produce a smooth, nice, warm sound. If I held it at an increasing angle, I'd get this rasp that mimicked the consonants from articulating a voice. That was another ingredient in making the guitar talk."

A fellow student, Dave Dilloway, also played guitar, and together with some other schoolmates, they formed an early band. The coverage included music from the Beatles, Manfred Mann, the Moody Blues, and other groups. By 1964, May was getting used to his new guitar and continued trying out new personnel, forming a band called 1984, the name taken from the George Orwell novel. His principal partner was vocalist and bassist Tim Staffell.

In the same year, British colonial rule in the far-off African Republic of Zanzibar was weakening. Now part of Tanzania, Zanzibar was then separate, and the island nation was cast into political chaos. One of the many families moving away to other locales to avoid potential violence was that of 17-year-old Farrokh Bulsara, a Parsi who had grown up in Zanzibar and also in India. (His father worked for the British Colonial Office.) Nicknamed Freddie, this young man was an accomplished pianist and aspiring artist and musician. With the revolution in Zanzibar, the Bulsara family moved to London to start life anew. In fact, they moved to a small house in Feltham only a few hundred yards away from that of Brian May.

Music+astronomy

For May, the balance between school and music was a fine line that sometimes teetered one way or the other. Described at the time as "serious-minded" or even "sheltered," May was expected to excel at his studies and then perhaps branch out and play and experience the world a bit by the time he was about 20. But many teenage

▲ **Freddie Mercury and Brian May** at the Marquee Club in London on December 20, 1972. © Queen Productions Ltd.

◀ **The famous homemade Red Special** is one of rock's most celebrated guitars. Brian May has played it for 48 years and counting. Richard Gray, © Duck Productions Ltd.

musical groups were moving away from their studies and following the Beatles' path to glory, or so they thought. "I completed my studies, O-levels [high-school-level exams], and applied for various universities," says May. Astronomy and space science had become increasingly attractive to him through his schoolwork.

Unlike most of his contemporaries, May did it all. In the music world, he saw Jimi Hendrix play in London, which transformed and inspired his idea of guitar playing and what it ought to be. 1984 was busy playing gigs, May adorned in Hendrix-style clothes and sporting Beatle-like hair. On May 13, 1967, the band played at Imperial College in London on the same bill as The Jimi Hendrix Experience, the day after the latter released its first album, *Are You Experienced?* Just after the new year, however, May quit 1984. A new band formed by May and Staffell recruited a blond-haired drummer they had met in the bar at Imperial College, Roger Taylor, age 18, who hailed from Cornwall. They wanted a "high-energy" drummer in the mold of Mitch Mitchell or Ginger Baker, and Taylor would produce admirably. The new band that started forward in 1968 would be called Smile.

"Jimi Hendrix really opened up the heavens," says May. "It's really hard to imagine the world without Jimi because he changed it so much. All of us thought we knew what guitar playing was. Jimi tore asunder all the limitations that none of us really knew were there." May saw Hendrix several times and sometimes went with Freddie. "And it was always the same — things would just be falling to bits around him, but it was the sound of heaven coming from the stage. Absolutely unreasonably colossal."

Academics rolled forward, too. May attended Imperial College, studying mathematics and physics among other subjects, and was graduated with an upper second-class degree. The physics was clearly leading to astronomy. On October 24, 1968, May received his Bachelor of Science degree in physics from the Queen Mother at the Royal Albert Hall. Two days later, Smile picked up considerable steam by opening for Pink Floyd.

Operating on all cylinders, May now applied for several academic posts. "I was offered a job in Jodrell Bank, which was just beginning to be an important radio astronomy facility in England," he says. "And Sir Bernard Lovell was there. That was a dream, really, but — being the kid that I was — I was so involved with music in London and didn't want to leave my friends. So I turned it down. I'm not proud of it because I'm not sure it was the right thing to do."

Instead, May accepted an offer to go to Imperial College, which would keep him in London, able to play music. May thought he was going to do infrared astronomy, which was really just beginning at the time. "The strange thing is that Professor Jim Ring, the

department head, was involved in optical spectrometry at the time and looking to radial velocities," says May. "And so I somehow got hooked into this whole program!" May thought he would be interested in working on radial velocities, but "was a little scared at the time because then spectrometry was a little arcane, or so I thought."

Ring and his colleagues were interested in a novel idea: looking at the radial velocities of particles in the zodiacal dust cloud and beginning to understand how dust in the plane of the solar system is moving. "This appealed to me," he says, "so I said, 'Yes, I'm your man — I'll take this on as a project!'" The researchers were looking for "clean" spectral lines that would allow them to detect Doppler shifts, indicating motion, and they settled on magnesium I, which corresponds to the easiest transition line of the magnesium atom.

"We looked for it in the zodiacal light," says May, "and, of course, the zodiacal light is not a very well-known phenomenon even to this day. But we were looking at this green line reflected in the dust and looking for a shift in the frequency of that line, which would then show us how the dust was moving." May and his colleagues were able to make a velocity map of the dust as opposed to what everyone else was doing, simply making positional maps. It was somewhat revolutionary at the time.

And when he wasn't working away on the dynamics of the zodiacal dust cloud, May kept hammering away with Smile. Throughout 1969, the band played gigs around London, and they picked up, from early on, an "ardent fan" who was "full of suggestions." This fan desperately wanted to be in the band and was quite a promising singer. "No," said May at the time. "Tim [Staffell] is the lead singer. He'd never wear it." The kid kept hanging around and slowly began to be noticed more and more by everyone. He was very shy but "cloaked in a persona," May recalls. The kid was Freddie Bulsara.

Here comes Queen

Freddie Bulsara spent the next few months looking for a band to sing with. He spent stints in Ibex and Sour Milk Sea, but by early 1970 spats and lineup changes left him looking for a band again. He and Roger Taylor each had a stand, selling clothes and gear, at London's hippy-fashionable Kensington Market. May, although still involved with Smile, was away, studying astronomy in Tenerife in the Canary Islands. He had a Spanish guitar on the mountain he had recently bought, and his professors, among them Jim Ring and Ken Reay, found his playing amusing. "I think Ken thought it was quite funny," says May. "He had a sly little smile on his face that said, 'Obviously, you'll never get anywhere.'"

When May returned to London, he found that Tim Staffell wanted to move on, and after some coaxing, Freddie wound his way into a new band that consisted of May, Taylor, Bulsara, and, for some months to come, a rotation of bass players. Eventually, by mid-1971, the guys found a bassist who would stay in John Deacon, a 19-year-old electronics student from central England who had played with some other London groups.

Well before then, two big name changes had occurred. Freddie suggested the new band's name, Queen, taken from the hippy world centered on Kensington Market, which prominently included gay culture — and Freddie would himself have gay relationships, although at this time he was still ensconced with his live-in lover, Mary Austin. Secondly, Freddie had written a song he really liked called "My Fairy King," which included the line "Oh Mother Mercury what have you done to me?" Freddie decided on a dramatic stage name change, and the world was introduced, slowly at first, to Freddie Mercury.

The band's first demo led to a first album, *Queen*, released in 1973. Its moderate success produced a tour mostly in England later that year.

"It's really hard to imagine the world without Jimi [Hendrix] because he changed it so much."

Queen got a big break when Mott the Hoople included them on a tour of England in 1973. © Queen Productions Ltd.

The 1975 hit "Bohemian Rhapsody" marked a turning point for Queen's success. Here, the band poses for a photo session for the single cover of the song. © Queen Productions Ltd.

◀ **Queen in concert** during 1980's *The Game* Tour. © Queen Productions Ltd.

▼ **A group shot** of Queen from 1979 during sessions for *The Game*, later used for the single release of "Save Me." © Queen Productions Ltd.

Goodbye, for now, to astronomy

During the Queen years, astronomy remained a passion in May's mind, but professional astronomy went dormant. "If I could ever maneuver my way into a place where there were clear skies at night, I would always do that on tour," he says. "I kept in touch with the guys at Imperial College and read some of the literature, but I wasn't really a student of astronomy during those years."

And yet he became a tour guide, showing the sky to many other musicians. "Lots of people really like that, and, of course, it's incredible how many people who live in cities rarely get to see the Milky Way, for instance," May says. "There were so many times when people have said, 'My God, I've never seen that!' when seeing the planets, or star clusters, or M31. It's nice to be able to share that with people who don't know about it."

As with many bands of the era, despite successful album releases and touring, Queen's individual members were slow to accumulate the benefits. This was partly due to the crazy system of the companies essentially fronting monies to the bands that had to be paid back to the labels, and to the dealings of the band's first manager, Norman Sheffield, who would be savagely remembered in Mercury's delightfully nasty song "Death on Two Legs (Dedicated to …)," from the 1975 album *A Night at the Opera*. But the band was achieving success and becoming famous, so May abandoned his astronomy, for the time being, to get on with rock 'n' roll. And Queen caught a big break when they toured with the established act Mott the Hoople.

A second album, *Queen II*, followed in 1974. The band toured England, Germany, and other parts of Europe in support in 1974 and continued their moderate success. Queen then went into its first tour of the United States, Canada, and Japan, which was planned for the first half of the year. But waking up in Boston, Massachusetts, one April morning, May found he was barely able to move. He gazed in the mirror, and his face was yellow. Doctors diagnosed him with hepatitis, and the tour stopped, Queen flying back to England and May recuperating in bed. A late 1974 tour concentrated on Europe.

Released near year's end, *Sheer Heart Attack* offered several hit songs, but it was the album's second track, "Killer Queen" — often claimed as "the most beautiful song ever written about a prostitute" — that really helped the band. At the time, Brian lived in a single room apartment in Earl's Court with his girlfriend, Christine Mullen. "We mainly lived on fish in a bag and cod fingers," he says. A London attorney, Jim Beach, began extricating Queen from its contracts, and soon the band signed with EMI and had new management. Now its success could move forward fairly. May and Mullen married in 1974, and the couple produced three children, James (now 34), Louisa (31), and Emily (25).

The next release, *A Night at the Opera*, made Queen international superstars. Not only was the album full of memorable and electric hits, but one of them, Freddie's "Bohemian Rhapsody," exploded as a huge smash. It began years earlier in Freddie's mind as "The Cowboy Song," a simple ditty that commenced with, "Mama, just killed a man." Inspired by the Beatles' "A Day in the Life," the song became a three-part "mock opera," in Freddie's words, whose middle operatic section married references to Galileo, the 17th-century Italian clown Scaramouche, Rossani and Mozart's operatic character Figaro, the Arabic prayer expression "bismillah," and the Spanish and Portuguese folk dance known as the fandango.

There was also Brian's great sci-fi folk song "'39," about interstellar travel; Roger's rocked-out "I'm in Love with My Car"; and John's sentimental "You're My Best Friend." Not to mention Freddie's lasting "Love of My Life" and Brian's working of "God Save the Queen," which would be used again and again as a live concert coda. Now Queen had arrived with unrelenting momentum, careening success, big money, unbounded critical acclaim, and another major touring romp in 1975 through Great Britain. From then on, the mere first keystrokes of Freddie's, hammering out the intro to "Rhapsody," would produce screams and cheers in concert. The sky was now the limit.

The next album, *A Day at the Races*, contained one of May's best straight-out rockers in "Tie Your Mother Down," which became a live favorite. It also contained a spectacular vocal gospel anthem, inspired by Aretha Franklin and written by Mercury, in "Somebody to Love," one of Freddie's

Freddie Mercury and Brian May record "One Vision" in the studio in 1985. © Queen Productions Ltd.

Brian May performs during the Montreal Forum show in early 1981 that was captured as the DVD *Queen Rock Montreal*. © Queen Productions Ltd.

favorites. "Freddie certainly loved that song at the time," says May. "It was all about Aretha Franklin for Freddie. She was a huge influence. I said to some people that I think sometimes Freddie wants to be Aretha in pretty clothes. So it was very much gospel construction and allowed him to sing in the way which he loved."

The band toured the United States, Japan, and Australia in early 1976. The following year saw an enormously long tour schedule around the world and the release of *News of the World*, a spectacularly successful album that contained two explosive hits. Having challenged each other to write "anthems" in which concertgoers could participate to the fullest, Brian composed "We Will Rock You," which since has become one of the best-known arena rock songs of all time. Its recording with the double thump followed by single hand clap came about when May found a bunch of loose boards in a studio hallway and the guys experimented with stomping on them followed by a clap. Freddie produced the anthem "We Are the Champions," a song so bold and outrageous in its ego that at first the other band members thought they simply couldn't do it.

The next album, *Jazz*, was released in 1978 and again contained some high-powered hits. Just as "We Will Rock You" and "We Are the Champions" were linked, Brian and Freddie created a twosome of songs for this release. Brian's tongue-in-cheek "Fat Bottomed Girls" was lyrically linked to Freddie's curious and poetic "Bicycle Race." The album also contained "Let Me Entertain You," which became a live favorite, and Freddie's "Don't Stop Me Now," which symbolized his increasingly rambunctious and reckless lifestyle in the gay community. When asked about his flamboyant and wild antics, Freddie simply retorted, "I sleep with men, women, cats, you name it."

The greatest band of the 1980s

Queen entered the 1980s with a new album, *The Game*, and a new and ambitious tour plan. This included the hits by Freddie "Play the Game" and one of Queen's biggest songs, "Crazy Little Thing Called Love." It also featured May's "Save Me," a hit and one that in later years would be used as a symbol for his campaigns against animal cruelty. Deacon's funk-inspired "Another One Bites the Dust" would also be a huge hit for the band all over the world. The band also recorded an album to serve as the soundtrack for the sci-fi film *Flash Gordon*.

> "If I could ever maneuver my way into a place where there were clear skies at night, I would always do that on tour."

1982's *Hot Space* included a big hit that resulted from a chance session with old London friend David Bowie. "Under Pressure" was an effort between Deacon, who came up with the repeating bass line, Bowie, and the other three Queen members — although at first May was unenthusiastic. The song and its famous scat singing by Mercury nonetheless caught on and became a huge concert staple.

Queen now routinely filled huge outdoor stadiums, and the band's incredible musicianship, Freddie's outrageous stage persona and amazing voice, and great songs had it riding high as the greatest band of the era. The pace was crushing, though, and things had to slow down a little. In 1984, *The Works* included May's hard-rocking "Hammer to Fall" and "Tear It Up," as well as Taylor's "Radio Ga Ga," inspired by his infant son's words. "Is This the World We Created ... ?," co-written by May and Mercury, soared in concert as an acoustic ballad. Deacon's "I Want to Break Free" was a big success that didn't fare well in the United States. The band's video featuring the guys in drag didn't work in the American Bible Belt, and Queen lost steam in America because of it.

Following another major tour, Queen was convinced to play in a fundraising event organized by Bob Geldof of the Boomtown Rats, who hoped to raise significant monies to combat widespread famine in Ethiopia. Called Live Aid, the event would consist of two concerts July 13, 1985, one at JFK Stadium in Philadelphia, Pennsylvania, and the other at Wembley Stadium in London.

Brian May rocks out on a solo in 2005 during the Queen+Paul Rodgers tour. © Queen Productions Ltd.

Amid an all-star lineup, Queen stole the show during its 21-minute set that opened with "Bohemian Rhapsody" and closed with "We Are the Champions." It was the band's greatest moment, witnessed by 1.9 billion people, and played out on its favorite stage at Wembley. May and Mercury closed out the show later in the day by playing and singing "Is This the World We Created ... ?," which seemed to have been made for the cause. "We wrote that song together as a rare event," says Brian. "We just sat down and said we need something personal and intimate, and talked about the state the world was in. It was one of those great moments when you can just feel it coming out. That was one of the few times we collaborated directly in that way."

But what was May's biggest memory of Live Aid? "Well," he says. "I think the moment when everyone's hands went into the air to 'Radio Ga Ga' was one, because the audience had not paid to see us. It was a great confirmation that people not only knew the song, but also had seen the video and knew what to do. The power of the video was amazing because the whole seventy thousand in the Old Wembley Stadium just erupted into that synchronized arm movement."

Live Aid reinvigorated Queen, and the band launched into another album, *A Kind of Magic*, and subsequent tour in 1986. Some of the songs had been written for the movie *Highlander*, and the hits were "One Vision," written as a shared credit by all four; Taylor's "A Kind of Magic"; "Friends Will be Friends," written by Deacon and Mercury; and May's "Who Wants to Live Forever." The tour, though limited to Europe, was the most extravagant stadium outing yet — and it would be the last one with Freddie Mercury. The last show all four would play together came August 9, 1986, at Knebworth Park, north of London.

In 1988, rumors swirled around Mercury's health as he appeared increasingly thin and gaunt. Denials came out quickly to protect him, but the truth was that he had contracted HIV and was increasingly ill. The band continued with albums but stopped touring. 1988's *The Miracle* presented special highlights in May's "I Want It All" and Mercury's "The Miracle." Two years later, *Innuendo* was released. The album featured three songs that struck a special chord with fans, especially watching a clearly ill Mercury working through the videos "I'm Going Slightly Mad," "The Show Must Go On," and "These Are the Days of Our Lives." In November 1991, as he was terribly sick and bedridden, Mercury issued a statement confirming he did have AIDS, and he died 24 hours later. The band's final album featuring all four musicians, *Made in Heaven*, was released four years after Freddie's death.

A new beginning — and back to astronomy

During the late 1980s, May had many challenges. Mercury's illness had a depressing effect on the band. "There was all that time when we knew Freddie was on the way out," he says, "we kept our heads down." Moreover, May's first marriage ended in 1988, and he fell into a serious depression that lasted into the early 1990s. He has even stated that he contemplated suicide. "My life was falling apart," he says. And, in a way, astronomy was responsible for bringing him back into a new life, one that came together after his struggles.

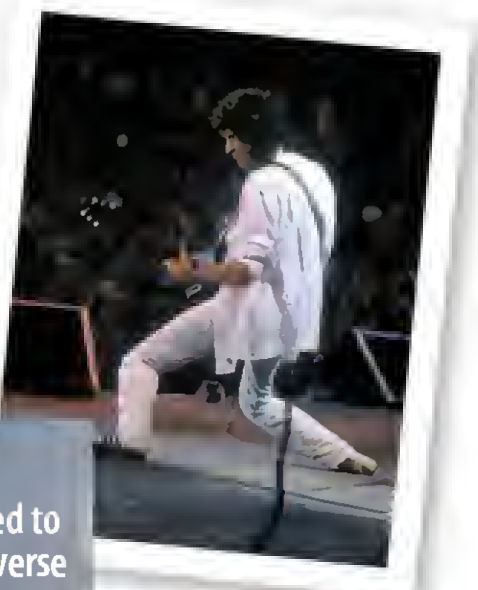
"I was deeply depressed," he says of this period. "I suppose I would call myself a spiritual person in a sense, but I don't really subscribe to any of the formal religions," says May. "I went to this clinic in Tucson, Arizona, when I was very down, and they said, 'We have to find your spirituality — what you most enjoy.' At the time, I couldn't think of anything I enjoyed. I was just in a very black place. And then eventually I figured out, because of the beautiful skies there, that one of my greatest joys was just looking at the stars. So I feel anchored to the universe in some way. It's quite a powerful force in my life."

"I feel anchored to the universe in some way. It's quite a powerful force in my life."

May says that seeing the dark night sky from Tucson was a driving force in getting him back on track. "I would look up at the stars and see Orion and the winter Milky Way and call them the brave stars because there seemed to be such strength up there that I could hook onto."

Music, of course, continued after Mercury's death. There was the Freddie Mercury Tribute Concert at Wembley in 1992. May also recorded several works with a changing lineup dubbed the Brian May Band. For several years starting in 2005, Queen+Paul Rodgers toured with the former lead singer of Free and Bad Company. One of May's biggest musical moments came in 2002 when he and Taylor played on the roof of Buckingham Palace to help celebrate Queen Elizabeth's Golden Jubilee — and something like a billion people saw it.

More recently, the band celebrated its 40th anniversary with a release of its whole catalog with numerous bonus tracks and with a special book, *40 Years of Queen*. And May has many other musical activities,



Brian May performs at one of Queen's Wembley Stadium concerts in July 1986, which would be among Freddie Mercury's last live shows. © Queen Productions Ltd.

playing here and there with British singer Kerry Ellis and recording with rap singer Dappy among them. A short time ago, May and Taylor announced concert dates this year as Queen, playing with *American Idol* vocalist Adam Lambert. And May married again in 2000, this time to Anita Dobson, actress on the British drama *EastEnders*, whom he had met in the late 1980s.

When asked about his own musical legacy, May replies, "Well, I suppose 'We Will Rock You' will be written on my tombstone because that's the one which connected so many people around the world. You know, every day people send me clips of their babies on YouTube singing it. Soon there will be a fetus in the womb going 'boom boom chick' with its feet and hands. I feel happy that it encircled the globe like that."

Meanwhile, astronomy reemerged into May's life with great force in the form of his old friend Sir Patrick Moore. "Patrick has been such a huge force in my life," he says. "We met for the first time when Patrick was playing himself in a radio drama that my friend Dirk Maggs was making for the BBC. So we actually did meet, and we did get on like a house on fire and have been firm friends ever since."

May had been out of astronomy for some time, and Patrick "invited me back in," he says. "I appeared on his *Sky at Night* program, the very program I'd been allowed to stay up late and watch as a kid. And from time to time, Patrick would just say, 'Why don't you finish off your Ph.D.?'"

May was skeptical. Hadn't the field changed too much in 30 years? Moore told him that in his particular area of motions in the zodiacal dust cloud, the research hadn't moved too much. "And the strange thing is," says May, "I started to talk about it in interviews, just as one of the things that was on my mind, and somehow the head of astrophysics at Imperial College heard one of the interviews and called me, inviting me to come back!" The offer was serious, and so, as Brian says, "Who's going to say no?"

So Michael Rowan-Robinson served as the advisor, and May finished the research. In 2007, he submitted his dissertation, and it was published by Springer-Verlag as *A Survey of Radial Velocities in the Zodiacal Dust Cloud*. The next year, he co-authored a popular astronomy book, *Bang! The Complete History of the Universe*, with Moore and Chris Lintott, published by Johns Hopkins. And the following year, his interest in

In recent years, Brian May has found a comfortable mixture of music, astronomy, stereography, and animal welfare activism — all of which were childhood passions. Brian May Archive

stereophotography produced a collaborative book with Elena Vidal, *A Village Lost and Found*, which presented the stereo views of an Oxfordshire village taken by T. R. Williams in the 1850s. (For more on May's interest in stereo imagery, see "Brian May's world of stereo astro pictures" in the January 2012 issue of *Astronomy*.)

When he's not playing music, worrying about astronomy, or fiddling with stereo photography, May is passionate about animal welfare, and he blogs about it on his website, www.brianmay.com. Fox hunting, badger culls, and other activities raise May's ire and keep him focused on journalists, members of Britain's Parliament, and the public with his energetic activism. "The interest in animals was always there," he says, "and I always promised myself that the time would come when I could devote time to doing something about it."

May is as busy as ever these days. "I'm ashamed to say I get so little time to observe the sky," he says. "I live in England, where you don't get clear skies very often, and if you do, you rush out with the first telescope that comes to hand." His favorite sky objects? "I get most excited about planets, so I'm a local man, really. I never get tired of Jupiter and Saturn." He was also a bit of a total solar eclipse addict for a while, seeing four or five eclipses out of eight or nine attempts. "That first time you see totality, you really understand where you are," he says, "on a piece of rock hurtling around the Sun. It's an awesome feeling — a life-changing experience."

Where does May see the next generation of astronomy enthusiasts, with so many young kids straying away from science? "Well, I guess we're entering a phase where knowledge for its own sake is not something that's amassed in the brain," he says. "In the days of Patrick Moore, you would learn lots of facts and figures and details about everything you came across. But I think things have changed an awful lot. There's more emphasis on using your smarts to analyze what the facts mean, and more checking of such a huge mass of data from references that are so easily available now. I think we're moving toward looking for the meaning in things rather than just the pictures."

He adds, with a laugh: "Although I love the pictures."

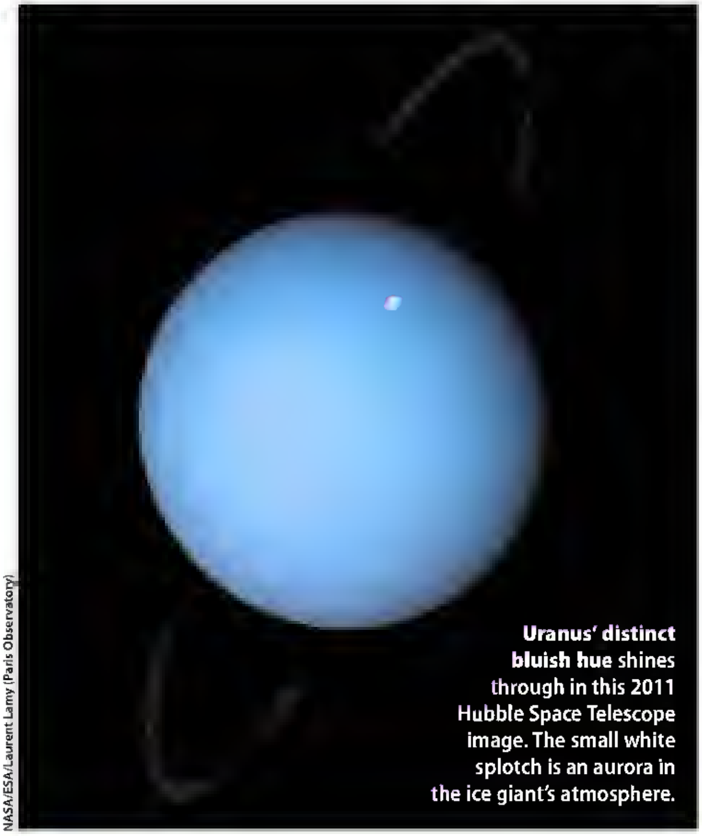
Enter to win an autographed copy of Brian May's dissertation at www.Astronomy.com/akindofmagic, and check out the full biography of Brian May at www.Astronomy.com/toc.

The Sky this Month

Martin Ratcliffe and Alister Ling describe the solar system's changing landscape as it appears in Earth's sky.

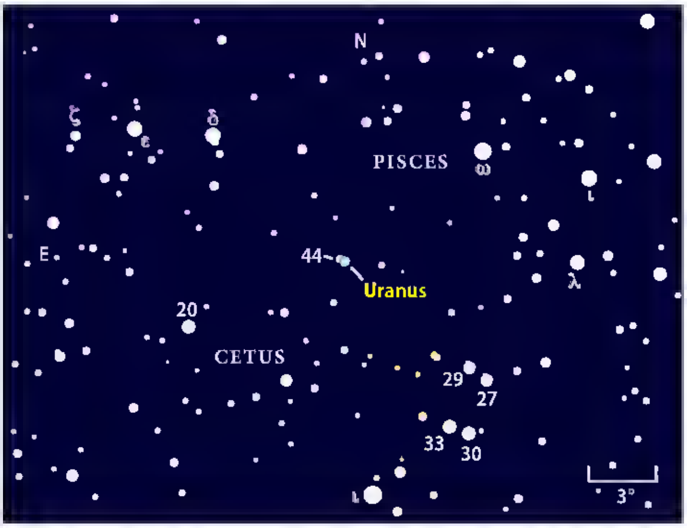
September 2012

Uranus reaches its peak



NASA/ESA/Laurent Lamy (Paris Observatory)

Uranus' distinct bluish hue shines through in this 2011 Hubble Space Telescope image. The small white splotch is an aurora in the ice giant's atmosphere.



Uranus glows at magnitude 5.7 during September. It lies near the border between Pisces and Cetus at opposition on the 29th. *Astronomy*: Roen Kelly

Saturn and Mars grace the twilight as September evenings unfold. Jupiter becomes the main attraction in the morning sky as it climbs high before dawn. Its companion for the past several months, brilliant Venus, now hangs lower in the sky. The morning "star" still offers early risers a treat, however, particularly when it passes near the fine Beehive star cluster in mid-September. In the solar system's outer reaches, Uranus and Neptune put on fine shows all night.

Our tour of the solar system begins in evening twilight, where three planets vie for attention. The lead player remains **Saturn**. The ringed planet lies about 10° high in the west-southwest an hour after the Sun goes down in early September. Shining at magnitude 0.8, it appears brighter than any other object in this part of the sky. Virgo's brightest star, magnitude 1.0 Spica, is a close second. You can find this luminary 5° below Saturn.

The star and planet sink lower with each passing day. By month's end, Saturn dips below the horizon just 60 minutes after sunset. It will pass behind the Sun in late October and return to view before dawn a few weeks later.

Saturn's low altitude means we must view it through more of Earth's turbulent atmosphere, so sharp views through a telescope will be hard to come by.

Still, the ringed planet looks mesmerizing and certainly is worth observing at low to medium magnification. In early September, the ring system spans 36" and tilts 14° to our line of sight. By the time Saturn returns to view in November, the rings will tilt 18° and appear even more spectacular.

If you look approximately 10° to Saturn's left in early September, your eyes will land on **Mars**. The Red Planet shines at magnitude 1.2, slightly but noticeably fainter than Saturn. Mars' ruddy glow contrasts nicely with the ringed planet's yellowish hue, particularly if you take advantage of the extra light-gathering power binoculars provide.

The two planets don't stay close for long. Mars moves rapidly eastward against the starry

background and travels from eastern Virgo through most of Libra this month. On September 15, the planet passes 1° south of the fine double star Zubenelgenubi (Alpha [α] Librae). Four days later, a waxing crescent Moon lies a couple of degrees to Mars' left. Unfortunately, the planet doesn't offer much to observers who target it through a telescope. Its 5"-diameter disk shows little, if any, detail.

Innermost **Mercury** makes a brief appearance low in the west as September ends. The planet stands 14° east of the Sun on the 30th, but most of that distance runs parallel to the horizon and not perpendicular. From 40° north latitude, Mercury appears a mere 2° high 20 minutes after sunset. Observers will need a flat, unobstructed horizon and a pristine sky to pick out the planet. Its one saving grace is that it shines brightly at magnitude –0.4.

Pluto resides less than 1° southwest of the easy-to-see open star cluster M25 in northern Sagittarius. This so-called dwarf planet is one of the largest solar system objects known beyond Neptune. Pluto lies far enough from the Sun, however, that it glows faintly at magnitude 14.1.

The distant world's westerly motion relative to the background stars halts September 17. It then heads slowly east and a bit south and, by the 30th, arrives within 7' of the 8th-magnitude star HD 170120, which is noticeable for its distinct orange color when viewed through a telescope. Although Pluto is difficult to see visually in an instrument smaller than 10 inches in aperture, it's a nice target for a CCD camera. In late September, aim at the orange star and take one 30-second image on two or three consecutive nights. You'll easily capture Pluto and its nightly motion.

Neptune currently lies 55° east of Pluto in the constellation Aquarius. The eighth

— *Continued on page 42*

Martin Ratcliffe *provides professional planetarium development for Sky-Skan, Inc., from his home in Wichita, Kansas. Meteorologist* **Alister Ling** *works for Environment Canada in Edmonton, Alberta.*

Meteor watch

The Epsilon Perseid meteor shower should produce about five meteors per hour the night of September 9/10. Observers will have Moon-free viewing during late evening. *Astronomy*: Roen Kelly

Will Perseus erupt two months in a row?

September typically is a month of few meteors, particularly when compared with the activity associated with August's Perseid shower. But there is hope. The International Meteor Organization (IMO) has identified a relatively new shower called the Epsilon Perseids. In 2008, observers saw an unexpected flurry of bright meteors emanating from Perseus. The shower remains active from September 4 to 14 and peaks the night of September 9/10.

For Northern Hemisphere viewers, Perseus rises in late evening. This leaves a few hours of dark skies before the Moon pokes above the horizon shortly after midnight local daylight time. Although the IMO doesn't expect a repeat of the 2008 outburst, the only people who will know for sure are those watching the sky.

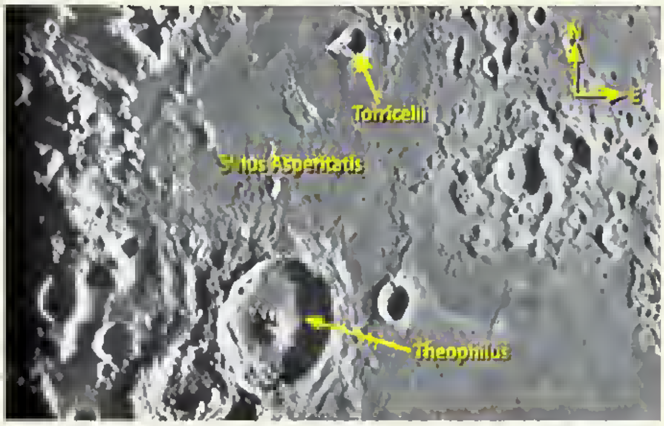
Rising Moon

Rough seas mark a crater's debris

If there's a best face to the Moon, it's the thick crescent seen a day or two before First Quarter phase. Smooth "seas" seemingly sport large waves, big craters take your breath away, and small impact scars stand out by casting long shadows. On the evening of September 20, the dramatic Serpentine Ridge is sure to grab your attention. This feature snakes north-south across the eastern part of Mare Serenitatis (the Sea of Serenity). Geologically speaking, it's a compression feature and not a frozen wave rippling through the lava.

Scan just south of the equator, and you'll find Theophilus, a sharp-edged crater that spans approximately 60 miles. Although it remains largely under the cover of night on the 20th, the Sun rises above the crater's rim on the 21st to produce a scene similar to the one pictured here. That's the best time to examine its complex jumble of central peaks and slumped terraces on the crater's walls. The impact that created Theophilus spread a rugged apron of debris northward into Mare Tranquillitatis (the Sea of Tranquility). Astronomers aptly named this region Sinus Asperitatis — the Bay of Roughness.

Also look closely at the unusual double crater Torricelli, located just north of Theophilus. Astronomers believe that its pear shape comes from a single glancing blow and not two unrelated events.



Sharp-edged crater Theophilus stands out shortly before First Quarter Moon. Look slightly north of this impact site for the jumbled terrain of Sinus Asperitatis and pear-shaped crater Torricelli. *Consolidated Lunar Atlas/UA/LPL*

Essentially, what was left of the impacting projectile blasted through the back wall as the crater was forming. Torricelli sits off-center in an ancient battered bowl filled to the brim with lava.

The all-sky map shows how the sky looks at:
10 P.M. September 1
9 P.M. September 15
8 P.M. September 30

Planets are shown at midmonth

How to use this map: This map portrays the sky as seen near 35° north latitude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

Star colors: Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.

Illustrations by *Astronomy*: Kellie Jaeger

Quick fact: The zodiacal light becomes visible before dawn for observers at midnorthern latitudes from approximately September 14 to 28.

Astronomy magazine

September 2012

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30						

Calendar of events

1 Venus passes 9° south of Pollux, 6 P.M. EDT

2 The Moon passes 5° north of Uranus, 8 P.M. EDT

3 Asteroid Parthenope is at opposition, 6 A.M. EDT

7 The Moon is at apogee (251,217 miles from Earth), 2:00 A.M. EDT

8 The Moon passes 0.6° south of Jupiter, 7 A.M. EDT

Last Quarter Moon occurs at 9:15 A.M. EDT

9 The Moon passes 0.6° north of asteroid Ceres, 5 A.M. EDT

10 Mercury is in superior conjunction, 9 A.M. EDT

12 The Moon passes 4° south of Venus, 1 P.M. EDT

15 New Moon occurs at 10:11 P.M. EDT

17 Pluto is stationary, 5 P.M. EDT

18 The Moon passes 0.8° south of Spica, 1 A.M. EDT

The Moon passes 5° south of Saturn, 10 A.M. EDT

The Moon is at perigee (227,268 miles from Earth), 10:49 P.M. EDT

19 The Moon passes 0.2° south of Mars, 5 P.M. EDT

22 Autumnal equinox occurs at 10:49 A.M. EDT

First Quarter Moon occurs at 3:41 P.M. EDT

23 The Moon passes 0.4° south of Pluto, 3 A.M. EDT

24 Asteroid Pallas is at opposition, 11 P.M. EDT

27 The Moon passes 6° north of Neptune, 7 A.M. EDT

Special observing date

29 Uranus reaches its 2012 peak today, shining at magnitude 5.7 and appearing 3.7" across through a telescope.

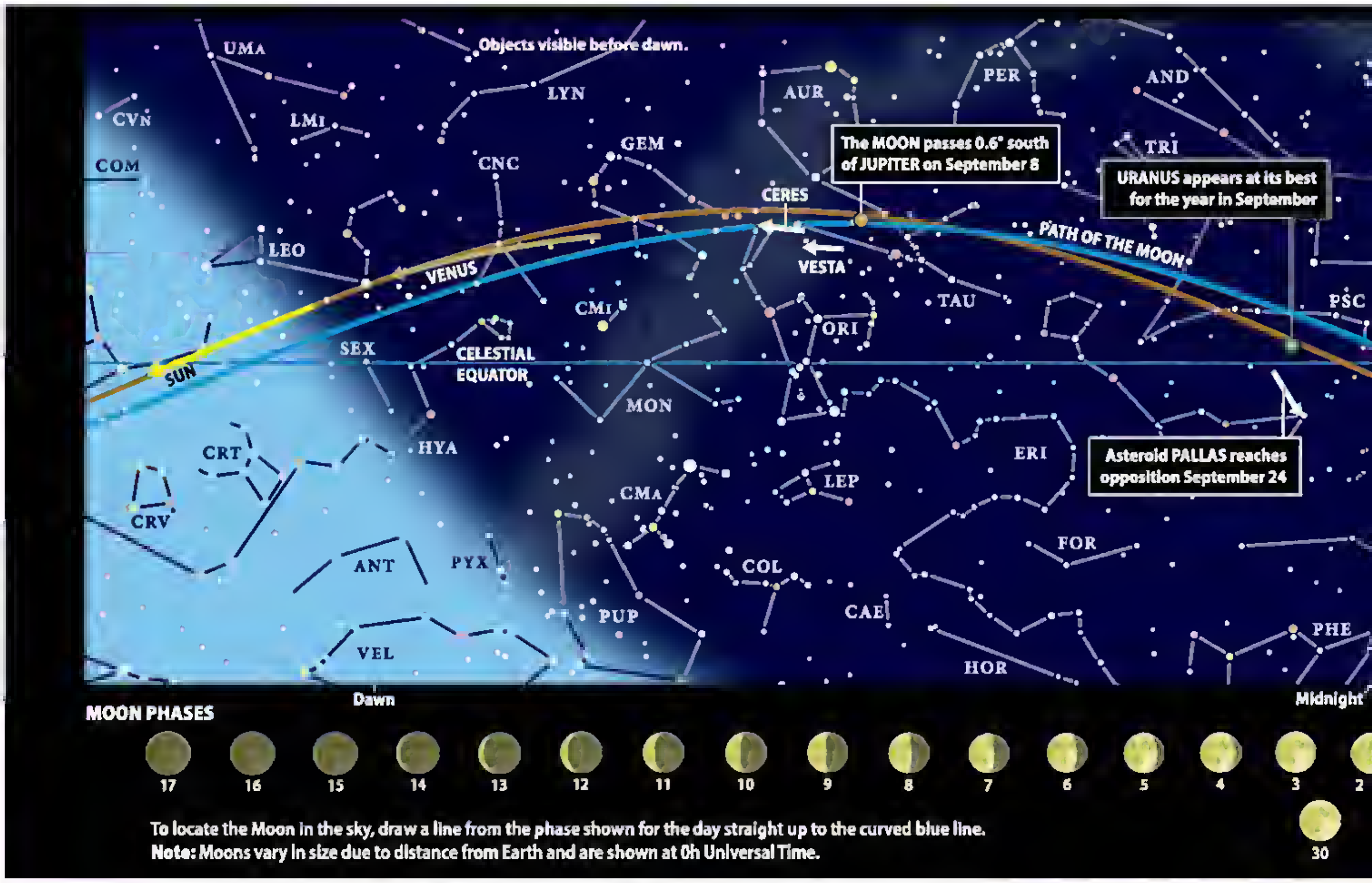
29 Uranus is at opposition, 3 A.M. EDT

Full Moon occurs at 11:19 P.M. EDT

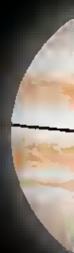
30 The Moon passes 5° north of Uranus, 1 A.M. EDT

Mercury passes 1.8° north of Spica, 10 P.M. EDT

Planets in September 2012



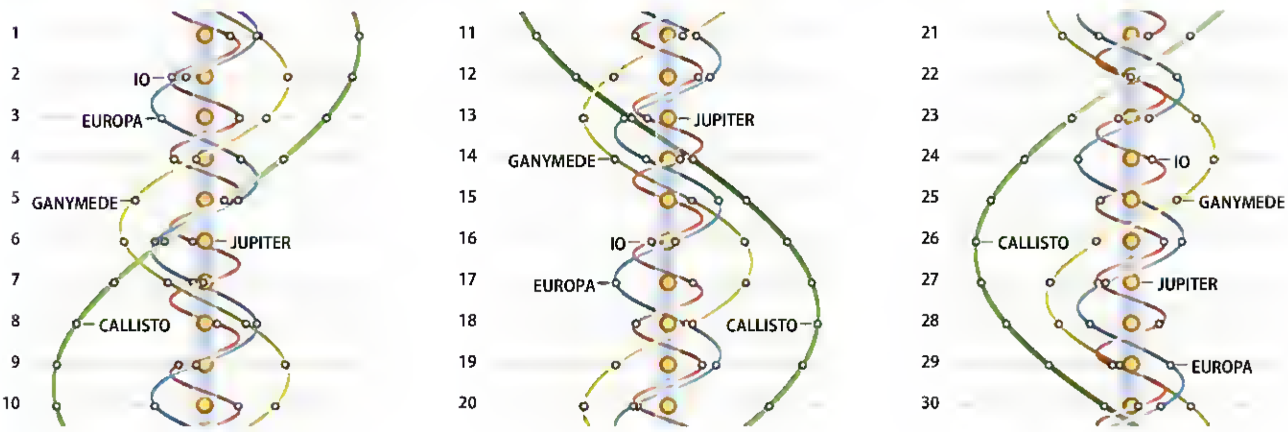


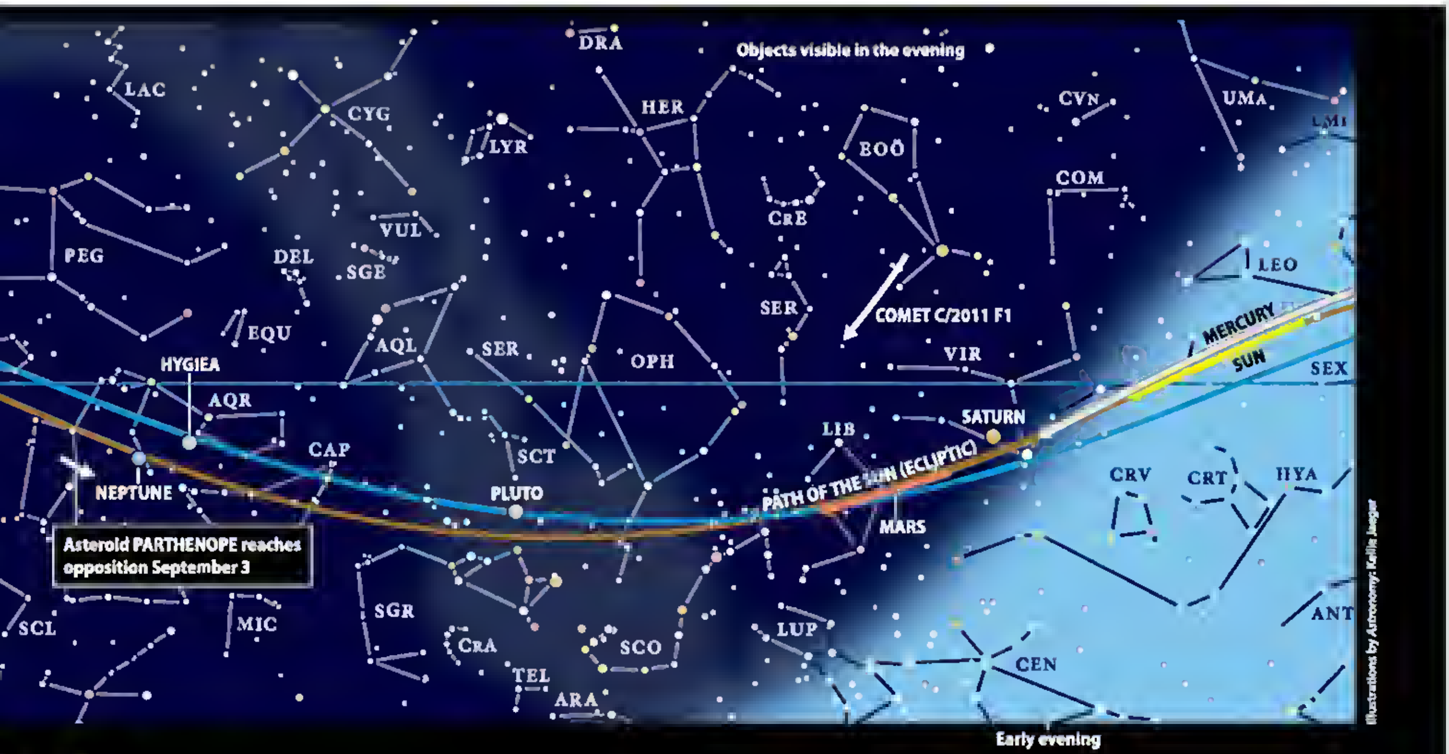
PLANETS	MERCURY	VENUS	MARS	CERES
Date	September 30	September 15	September 15	September 15
Magnitude	–0.4	–4.2	1.2	8.7
Angular size	5.0"	17.7"	5.0"	0.5"
Illumination	92%	65%	92%	97%
Distance (AU) from Earth	1.353	0.941	1.871	2.638
Distance (AU) from Sun	0.457	0.722	1.484	2.741
Right ascension (2000.0)	13h19.2m	8h44.7m	14h47.4m	5h48.7m
Declination (2000.0)	–8°38'	17°07'	–16°50'	20°38'

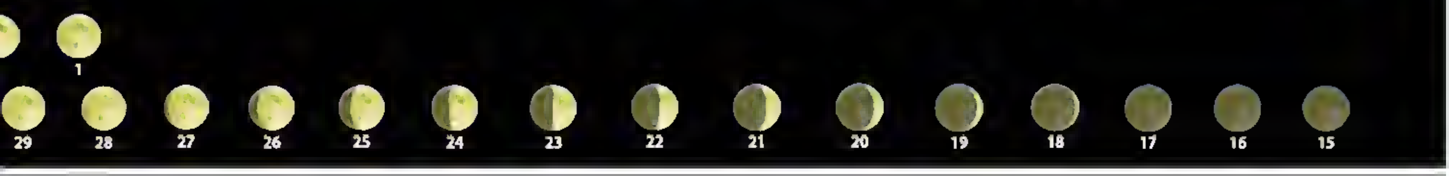
Jupiter's moons

Dots display positions of Galilean satellites at 4 A.M. EDT on the date shown. South is at the top to match the view through a telescope.



This map unfolds the entire night sky from sunset (at right) until sunrise (at left).
Arrows and colored dots show motions and locations of solar system objects during the month.

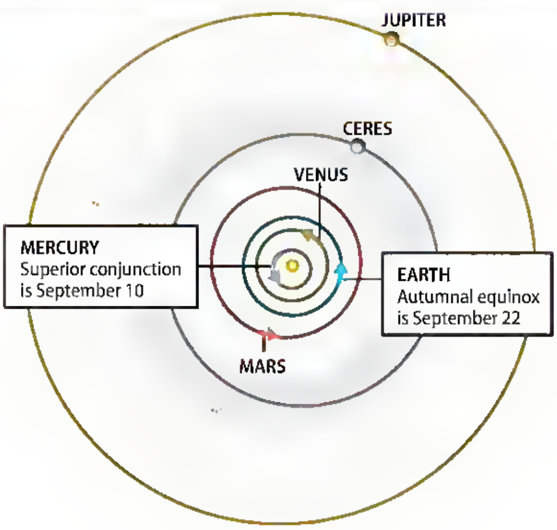


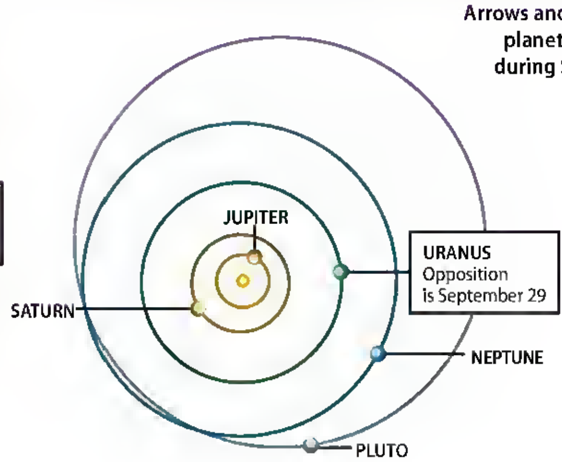


JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
September 15	September 15	September 15	September 15	September 15
–2.4	0.7	5.7	7.8	14.1
41.0"	15.7"	3.7"	2.4"	0.1"
99%	100%	100%	100%	100%
4.812	10.569	19.089	29.056	32.034
5.031	9.764	20.064	29.994	32.299
4h57.7m	13h45.3m	0h26.7m	22h13.0m	18h28.7m
21°51'	–8°27'	2°04'	–11°42'	–19°38'

The planets in their orbits

Arrows and dots show planets' positions during September.





— *Continued from page 37*

When to view **the planets**

EVENING SKY	MIDNIGHT	MORNING SKY
Mercury (west)	Jupiter (east)	Venus (east)
Mars (southwest)	Uranus (southeast)	Jupiter (southeast)
Saturn (west)	Neptune (south)	Uranus (west)
Uranus (east)		
Neptune (southeast)		

planet reached opposition and peak visibility in late August, and it remains a fine target through binoculars and telescopes all night.

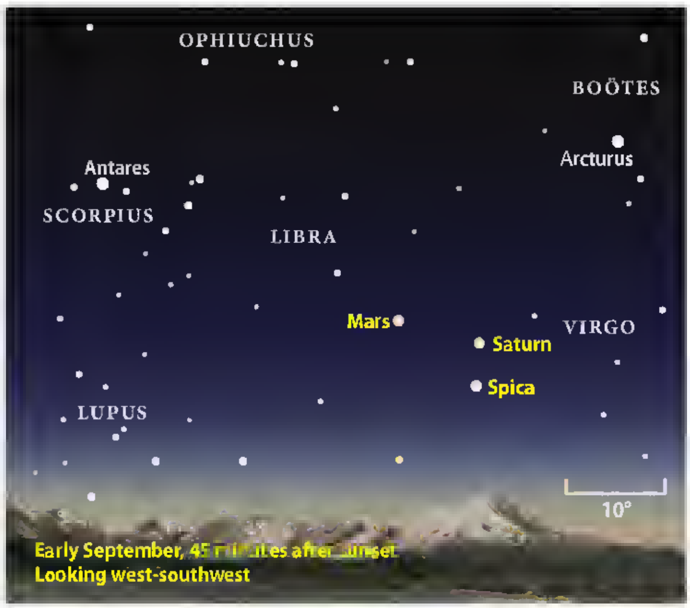
You can find it in the same binocular field as both 4th-magnitude Iota (ι) Aquarii and 5th-magnitude 38 Aqr (which resides 2.5° north-northeast of Iota). The planet begins September nearly 1° due east of the latter star and closes the month just 22′ southeast of it.

Neptune glows at magnitude 7.8, just within range of handheld 7x50 binoculars. When mounted on a tripod, the same binoculars easily reveal Neptune as well as many fainter stars. Use your telescope and a high-power eyepiece to see the planet's 2.4″-diameter disk and blue-gray color.

Head one constellation farther east, and you'll land on the current home of **Uranus**. This planet reaches opposition September 29, when it lies opposite the Sun in our sky and remains visible from sunset to sunrise. This configuration also brings Uranus closest to Earth, so it glows brighter and appears larger through a telescope than at any other time this year. One day after opposition, the Full Moon passes 5° north of the planet.

Uranus peaks at magnitude 5.7, although it doesn't appear perceptibly fainter at any other time this month. Its magnitude makes it just bright enough to see with naked eyes if you observe under a dark sky. Binoculars or a telescope show the planet with ease. A telescope reveals Uranus' disk, which spans 3.7″ and displays a distinct blue-green hue.

You can find the planet on the border between Pisces and Cetus. It lies near the equally bright star 44 Piscium. On September 22, Uranus appears 1.4′ due east of the star, and the two will look like a bright double through a telescope. Their distance remains the same on the following night, but the planet



Mars, Saturn, and Spica dip deeper into the twilight during September, but views early in the month should still be impressive. *Astronomy*: Roen Kelly

Comet search

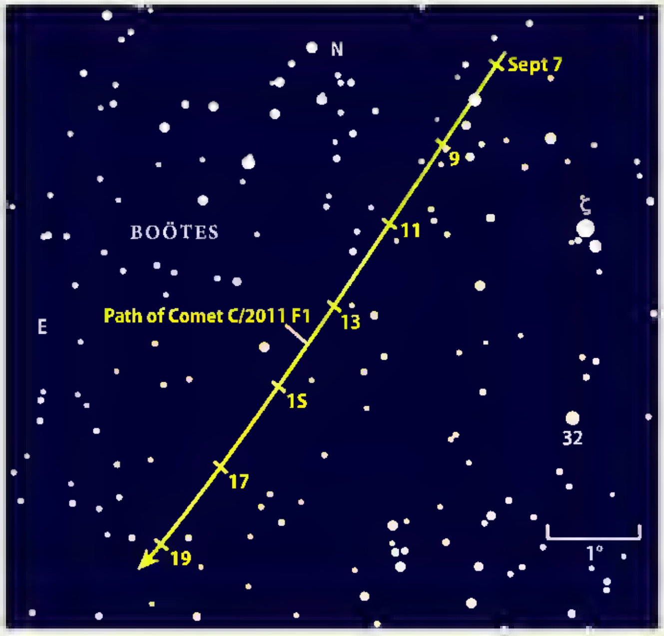
A dirty snowball invades the Herdsman

Comet hunters have no time to lose after darkness falls this month. Head outside about 90 minutes after the Sun sets and find magnitude 0.0 Arcturus. This bright star lies low in the west and displays a noticeable orange hue. (Use the circular StarDome map on pages 38 and 39 to locate Arcturus.)

Eight degrees southeast of Arcturus lies 4th-magnitude Zeta (ζ) Boötis, our jumping off point for locating Comet C/2011 F1 (LINEAR). You'll likely need a 6-inch or larger telescope and a dark country sky to bag this faint fuzzball, which astronomers expect to glow at 10th or 11th magnitude. Try to observe during the second or third week of September when the Moon is gone from the evening sky.

The comet will not be an easy target. Spotting it is like finding a specific tree when you've been dropped into the middle of a forest. Unless you've got a big scope, you likely won't see the comet at low power. Bump up the magnification past 100x and slowly spiral out from the position marked on the finder chart. Motion helps your eye pick out a small, soft glow.

Although C/2011 F1 soon will disappear in the Sun's glare, a recently discovered comet — C/2012 K5 (LINEAR) — should take its place this winter. That would satisfy us until spring, when we may see our first bright naked-eye comet in a few years. Astronomers expect C/2011 L4 (PanSTARRS) to reach at least 3rd or 4th magnitude when it comes into view in March and April 2013.



Comet C/2011 F1 (LINEAR) might reach 10th magnitude this month as it treks through southern Boötes. Your best looks will come when the Moon is gone from the evening sky around mid-September. *Astronomy*: Roen Kelly

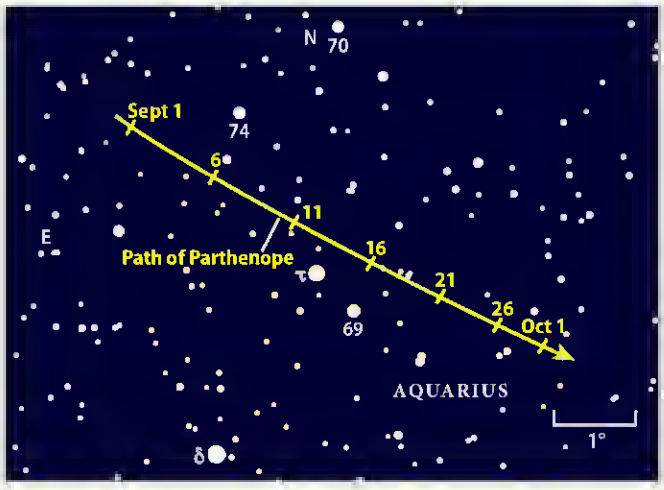
Locating **asteroids**

Spy a mermaid swimming the autumn sky

The celestial embodiment of the mermaid Parthenope slides through the constellation Aquarius the Water-bearer during September. Glowing at 9th magnitude, the main-belt asteroid 11 Parthenope is bright enough to see easily through a 6-inch telescope from the suburbs or large binoculars from a dark-sky site. Wait until late evening for this region to climb higher in the sky. It's also best to avoid the beginning and end of the month when a bright Moon lies nearby.

No conspicuous stars occupy southern Aquarius, but a pair of modest ones will get you to the asteroid's vicinity. Delta (δ) Aquarii and Tau (τ) Aqr represent the stream of water running from Aquarius' amphora into the mouth of Piscis Austrinus the Southern Fish. Parthenope passes within 1° of Tau in mid-September. Use the chart to pinpoint the asteroid, or sketch the field and return to the same area the next night; the object that moves is the space rock.

In January 2011, nearly 20 amateur astronomers timed Parthenope as it blocked the light of a background star. From these observations, astronomers determined that the asteroid is a potato-shaped rock 93 miles across its longest dimension.



Ninth-magnitude Parthenope marches through southern Aquarius in September, passing within 1° of the moderately bright star Tau (τ) Aquarii at midmonth. *Astronomy*: Roen Kelly

then appears southwest of the star. By month's end, 18' separate the two objects.

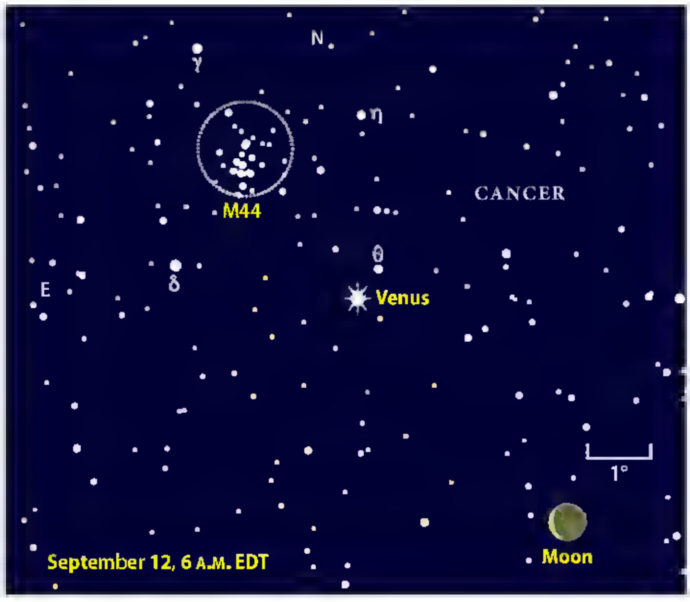
Brilliant **Jupiter** dramatically changes the familiar appearance of Taurus the Bull, standing less than 10° northeast of the Hyades star cluster all month. Although the giant planet rises before midnight local daylight time, the best views come as it climbs higher before dawn. It shines at magnitude –2.4, making it the brightest night-sky object other than the Moon and Venus. The Last Quarter Moon passes within 1° of Jupiter the morning of September 8.

The planet puts on a show for those who view it through a telescope. Jupiter's equatorial diameter grows 10 percent this month, from 39" to 43", as it approaches Earth. The gas giant's dynamic atmosphere is one of the solar system's visual highlights, and it's on display every clear night. The most prominent features are two dark equatorial belts that straddle a brighter zone and the Great Red Spot, which now appears a subtle pink. Under good conditions, a series of alternating belts and zones appears. Experienced observers patiently watch Jupiter over many minutes to catch occasional moments of great seeing, when fine details pop into view.

You need no experience to marvel at the planet's four bright moons: Io, Europa, Ganymede, and Callisto. Their orbits carry them into different configurations each night and often from one hour to the next. Use the diagram at the bottom of page 40 to identify each moon.

Dazzling **Venus** rises around 3 A.M. local daylight time during September. It appears among the background stars of eastern Gemini on the 1st, some 9° south of 1st-magnitude Pollux. At magnitude –4.3, the planet outshines the star by more than 100 times.

Venus crosses into the decidedly fainter constellation Cancer on September 4. But a stunning alignment awaits observers September 12. That morning, a waning crescent Moon stands 4° southwest of Venus while the planet lies 3° southwest of the Beehive star cluster (M44). The scene should be nice with naked eyes, but binoculars will deliver the best views. On the next two mornings, Venus passes 2.5° south of the Beehive. The planet spends September's final week in western Leo, not far from 1st-magnitude Regulus.



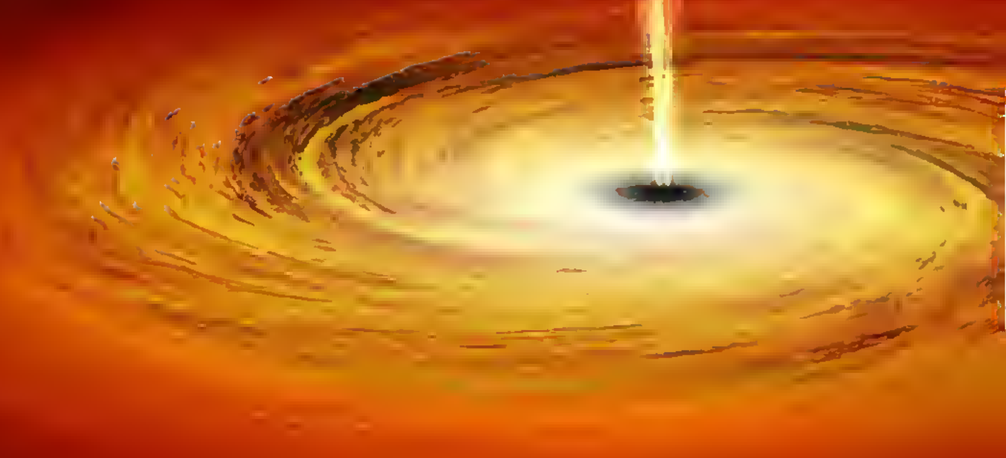
Venus meets the swarm of stars known as the Beehive Cluster (M44) in mid-September. Binoculars deliver great views, particularly when a waning crescent Moon joins the scene on the 12th. *Astronomy*: Roen Kelly

To see Venus well through a telescope, wait until twilight begins, which reduces the contrast between planet and sky. During September, Venus' disk shrinks from 20" to 16" across while its phase waxes from 58 to 70 percent lit.

The autumnal equinox occurs at 10:49 A.M. EDT September 22. As Earth orbits our star, the Sun wanders against a backdrop of invisible constellations. It lies in Virgo at the equinox, at the precise point where the ecliptic crosses the celestial equator. This brings nearly equal portions of day and night to most places on Earth except at the poles, where the Sun takes all day to circle the horizon.

BLACK in our backyard

Black holes are the most astounding objects in the universe. And at least 19 of them lurk within the Milky Way. **by Richard Talcott**



Until Swiss astronomers Michel Mayor and Didier Queloz discovered the first planet orbiting a Sun-like star in 1995, scientists faced a dilemma: They *thought* such planets should be common, but they had no *proof*. Fast-forward 17 years and the verdict is in — the number of confirmed exoplanets now totals several hundred and should pass the 1,000 mark in the next year or two.

The discovery of black holes followed a similar trajectory. By the early 1990s, most astronomers suspected these bizarre objects existed, but confirmation was hard to come by. Scientists like to say that extraordinary claims require extraordinary proof, and things don't get much more astonishing than black holes. These bodies possess a gravitational pull so powerful that nothing, not even light, can escape their clutches. Information about what happens inside a black hole can never leave — a cosmic equivalent to Las Vegas.

Fortunately, the suburbs of Vegas are more forgiving. Material in a black hole's vicinity suffers conspicuously from the intense gravity. Wayward stars move abnormally fast, and gas becomes superheated and radiates copious amounts of light. Astronomers confirm a black hole's existence when they see these signatures and can eliminate all other possible causes. In the past 15 years or

HOLES

The black hole in Cygnus X-1 rips material from its supergiant companion in this artist's concept. Most of the captured gas forms a broad, million-degree accretion disk, but magnetic fields channel some of it into high-speed jets. NASA/CXC/M.Weiss

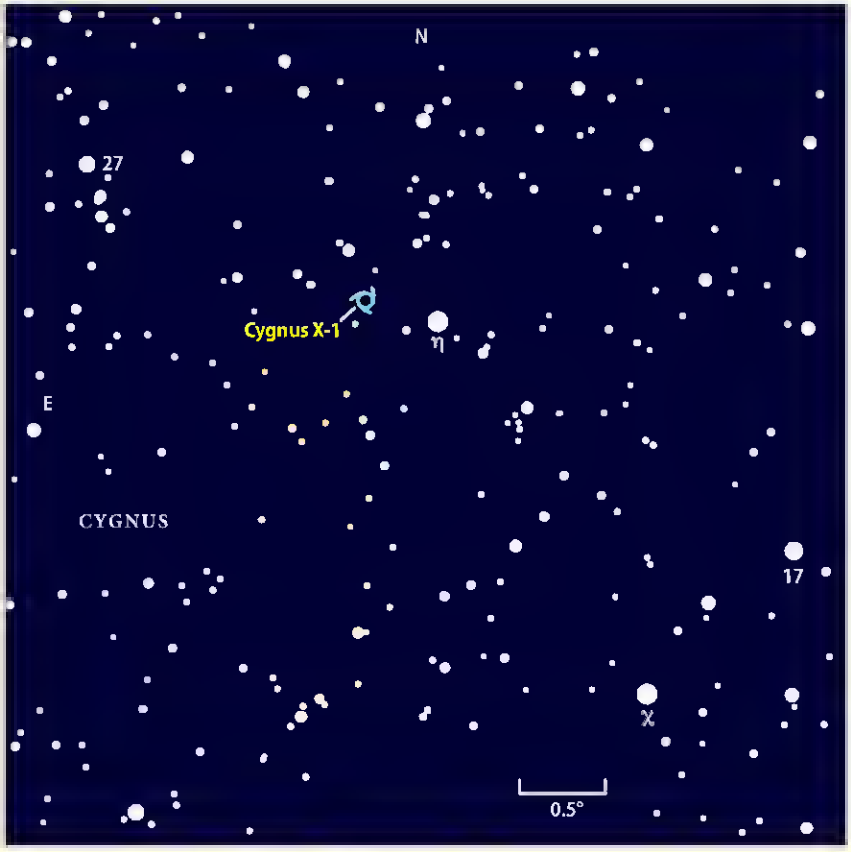
so, the tally of black holes in our galaxy has reached 19 — 18 reside in X-ray-emitting binary star systems, and one lurks in the Milky Way's core. But many more likely remain beyond astronomers' current reach.

From Newton to Einstein

In the late 1700s, British professor John Michell and French astronomer and mathematician Pierre-Simon Laplace advanced the idea of what Laplace called "dark bodies." Using Isaac Newton's concepts of light and gravity, they reasoned that the gravitational pull of a massive star could be large enough to prevent light from escaping.

Unfortunately, Newton's theory could not describe what happens when gravity grows this strong. That understanding wouldn't come until Albert Einstein developed his general theory of relativity in the 1910s. Relativity, which treats gravity as a distortion of space-time, allows physicists to describe black holes in gory detail. Still, it took decades before most scientists considered these objects more than theoretical curiosities.

The reality of black holes began to emerge once astronomers understood how massive stars die. If a star begins life with more than about eight times the Sun's mass, it will not experience a quiet demise. When such a star exhausts its nuclear fuel, its core collapses. This triggers a shock wave that destroys the rest of the star in a



The relatively nearby black hole Cygnus X-1 has a 9th-magnitude blue supergiant companion that shines brightly enough to show up through amateur telescopes. You can find it 0.4° east-northeast of the 4th-magnitude star Eta (η) Cygni. *Astronomy:* Roen Kelly

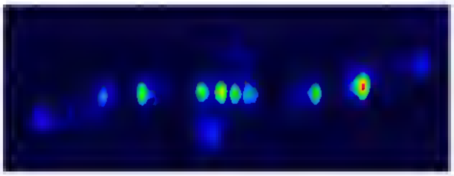
Track down a black hole

By definition, black holes give off no light. This makes the idea of trying to see one sound a bit challenging. Fortunately, black holes don't always live in isolation, and one of the most famous — Cygnus X-1 — has a partner that shows up through any backyard instrument.

Cygnus X-1's stellar companion is a blue supergiant cataloged as SAO 69181. This star shines at magnitude 8.9 in the central regions of the constellation Cygnus the Swan, which passes nearly overhead on September evenings for observers at mid-northern latitudes.

Use the circular StarDome map at the center of this issue to locate Cygnus. Next, home in on Eta (η) Cygni, a 4th-magnitude star that lies 13° southwest of the Swan's luminary, 1st-magnitude Deneb. Scan 0.4° east-northeast of Eta to find SAO 69181. It's the middle object in a line of three equally bright stars. When you spot it, you won't be seeing light from the black hole, but it will be literally from the next closest thing. — *R. T.*

Cygnus X-1 radiates strongly in X-rays because the temperature in the black hole's accretion disk surpasses 1 million degrees. The Chandra X-ray Observatory captured this glow during a 16-hour observation. NASA/CXC/SAO



SS 433 contains a normal star orbiting a compact object, which is surrounded by an accretion disk that feeds two radio-emitting jets. Astronomers don't know if the compact object is a neutron star or a black hole. Amy Mioduszewski, et al. (NRAO/AUI/NSF)

brilliant supernova that can shine with the light of 10 billion Suns. In most cases, the core left behind weighs between 1.4 and 3 solar masses and has been crushed into a sphere the size of a major city. A single teaspoonful of this so-called neutron star would weigh close to a trillion tons.

Yet even this exotic end state pales in comparison with what happens to the

Richard Talcott *is an* Astronomy *senior editor and author of* Teach Yourself Visually Astronomy *(Wiley Publishing, 2008).*

rarest of stars that start life with more than 30 solar masses. In 1939, physicists J. Robert Oppenheimer and Hartland Snyder showed that when such a star dies, its collapsed core (which weighs more than three Suns) is too heavy to settle down as a neutron star. It creates a region of space-time cut off from the rest of the universe because no light can ever escape. Thirty years later, physicist John Wheeler coined the descriptive term *black holes* for these objects.

Black holes possess only three characteristics: mass, spin, and charge. All other properties of the collapsing star are lost. And because stars rarely have any excess positive or negative charge, mass and spin describe most black holes.

A key feature of a black hole is its "event horizon" — the radius at which a beam of light would just fail to escape. Any event that takes place within this horizon can never be glimpsed from outside. For a nonspinning, 10-solar-mass black hole, the event horizon spans approximately 37 miles (60 kilometers). Double the mass, and the diameter also doubles. A black hole spinning at the maximum possible rate has a diameter half that of a nonrotating one with the same mass.

The galaxy's black holes

Because telescopes cannot see inside the event horizon, astronomers must search for a black hole's impact on its immediate surroundings. Some binary star systems offer a perfect environment. The massive stars that create black holes evolve quickly, typically running through their nuclear fuel in a few million years.

After the star explodes (the companion usually survives), the black hole's intense

gravity may pull material from its neighbor's outer layers. This gas falls toward the black hole and forms an accretion disk that swirls around the invisible object like water circling a drain. As the material moves ever faster, friction among the atoms heats it to millions of degrees. Gas at this temperature emits lots of X-rays, which Earth-orbiting observatories can detect.

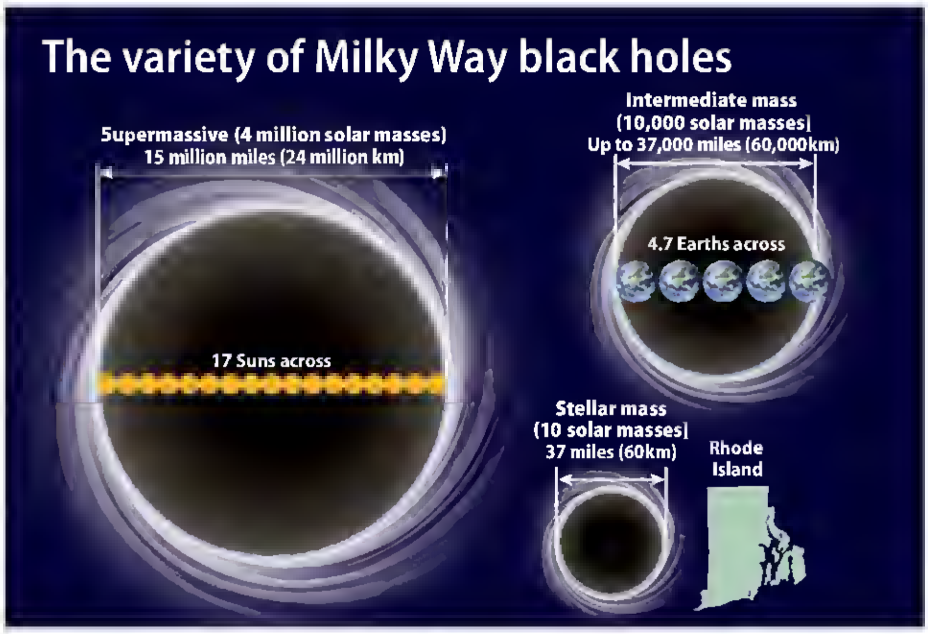
So, to detect a black hole, astronomers look for an X-ray-emitting binary system comprising one normal star and an invisible but massive companion. Lots of these objects exist in the Milky Way, but not all contain black holes. Neutron stars in a binary can produce the same behavior, and because they radiate little light, they can't be detected across large distances.

To differentiate between the two possibilities, astronomers need to pin down the compact object's mass. General relativity says that a stable neutron star can't weigh more than three Suns. Any invisible companion bigger than that must be a black hole — assuming, as almost every scientist does, that relativity accurately describes such strong gravitational fields. To find the object's mass, astronomers must measure the binary system's orbit precisely.

Ronald Remillard of the Massachusetts Institute of Technology in Cambridge and Jeffrey McClintock of the Harvard-Smithsonian Center for Astrophysics (also in Cambridge) have compiled the most up-to-date list of black holes in binary systems. Our galaxy contains 18; their locations and properties appear on page 49.

But this list likely forms only the tip of the iceberg. Remillard and McClintock count 20 more binary systems that show similar X-ray signatures but have no detailed orbital information to provide masses. (Astronomers haven't even seen an optical counterpart in most of them.) And nearly every scientist suspects far greater numbers of black holes exist either alone in space or in more widely separated binaries that don't emit X-rays. Astronomers estimate that the Milky Way holds between 100 million and 1 billion black holes.

Globular cluster M15 may harbor a nearly 1,000-solar-mass black hole. Scientists continue to argue if M15 and other globulars contain intermediate-mass black holes. NASA/ESA/The Hubble Heritage Team (STScI/AURA)

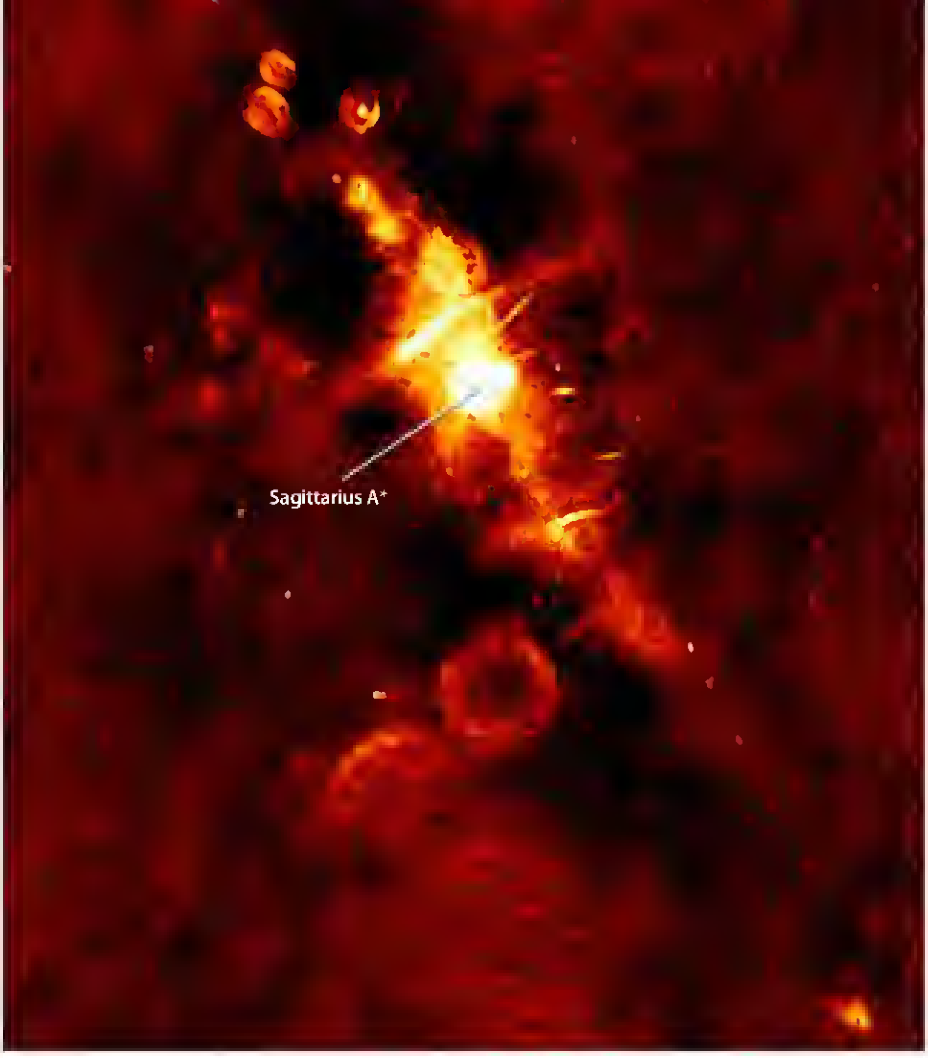


Eighteen of the galaxy's 19 known black holes weigh between three and about 15 times the Sun's mass but have diameters the size of a small state. If intermediate-mass black holes exist, they would extend a few Earth diameters. The central supermassive black hole spans 17 Suns. *Astronomy*: Roen Kelly

The Swan's song

The most famous stellar-mass black hole is Cygnus X-1 (its designation signifies it as the first X-ray source discovered in Cygnus the Swan), which lies some 6,100 light-years from Earth. It is the only one in a high-mass X-ray binary system — its companion star is a blue supergiant that tips the scales at approximately 19 solar masses. In fact, this luminous companion shines brightly enough that it appears in our sky as a 9th-magnitude star visible through amateur telescopes (see "Track down a black hole" on page 46).

The black hole in Cygnus X-1 weighs close to 15 solar masses, which makes it the heaviest one known in a binary system. The two objects orbit each other once every 5.6 days at an average distance about half that between the Sun and Mercury. As matter in the accretion disk falls toward the black hole, magnetic fields channel some of it into a pair of high-speed jets that emerge perpendicular to the disk. Recent observations show that the black hole rotates at more than 90 percent of the theoretical maximum.



The Milky Way's core contains a black hole weighing some 4 million solar masses. This supermassive object, dubbed Sagittarius A*, glows at radio wavelengths (seen here) and in X-rays but disappears in visible light because so much dust lies between Earth and the galactic center. NRAO/AUI/NSF

The other 17 stellar-mass black holes reside in low-mass X-ray binaries. Most of their companion stars have masses similar to or somewhat smaller than the Sun. Still, a few of these objects stand out. Astronomers estimate the mass of GRS 1915+105 (a designation that comes from the Russian Granat satellite and the object's sky coordinates) in Aquila at 14 Suns, but with an uncertainty of 4 solar masses, it could be the heavyweight champ. This object also spews jets that appear to travel faster than the speed of light — an optical illusion that arises because the jets move at about 90 percent light-speed toward Earth. It marked the first time scientists had seen such superluminal motion within our galaxy.

Meanwhile, GX 339-4 lies in the southern constellation Ara and experiences frequent X-ray outbursts followed by periods when its emission decreases, but never so far as to let its companion star shine through. It's the only binary black hole whose companion still eludes detection.

Just because a binary system behaves oddly doesn't mean it possesses a black hole, though. Few objects in the galaxy sport the peculiarities of the high-mass X-ray binary SS 433, which lies inside a 10,000-year-old supernova remnant called W50. The explosion that created this glowing remnant gave birth to a compact object that now steals material from a massive companion star. The gas forms an accretion disk that powers two jets beaming in opposite directions like a pair of rotating lighthouse beacons. Many astronomers think SS 433's compact object is a black hole, but they can't rule out a neutron star.

Black holes in globulars?

The biggest stellar-mass black holes in our galaxy appear to top out at about 15 to 20 times the Sun's mass. Yet a number of scientists think much larger ones exist in some of the galaxy's 150 or so globular star clusters. Star-sized black holes likely formed in these clusters early in their histories, more than 10 billion years ago, and fairly quickly sunk to the center. But what happened to these black holes? Some theorists think that they merged with other black holes or neutron stars and grew much bigger, while others suspect that they encountered other stars that then ejected them from the cluster.

Thomas Maccarone of the University of Southampton in England and his colleagues reported in 2007 on the best candidate for a black hole in any globular cluster. They found an X-ray source in a globular circling the giant elliptical galaxy M49, located some 50 million light-years away in the Virgo cluster. The object emits far too many X-rays to be a neutron star and so must be an accreting black hole. Its mass exceeds 20 Suns but could be much higher.

The case for black holes in our galaxy's globulars is more tenuous. Unless a black hole actively feeds on material from another star, it won't have an accretion disk that glows in X-rays. The best alternative method is to look at the brightnesses and motions of the stars near a cluster's center.

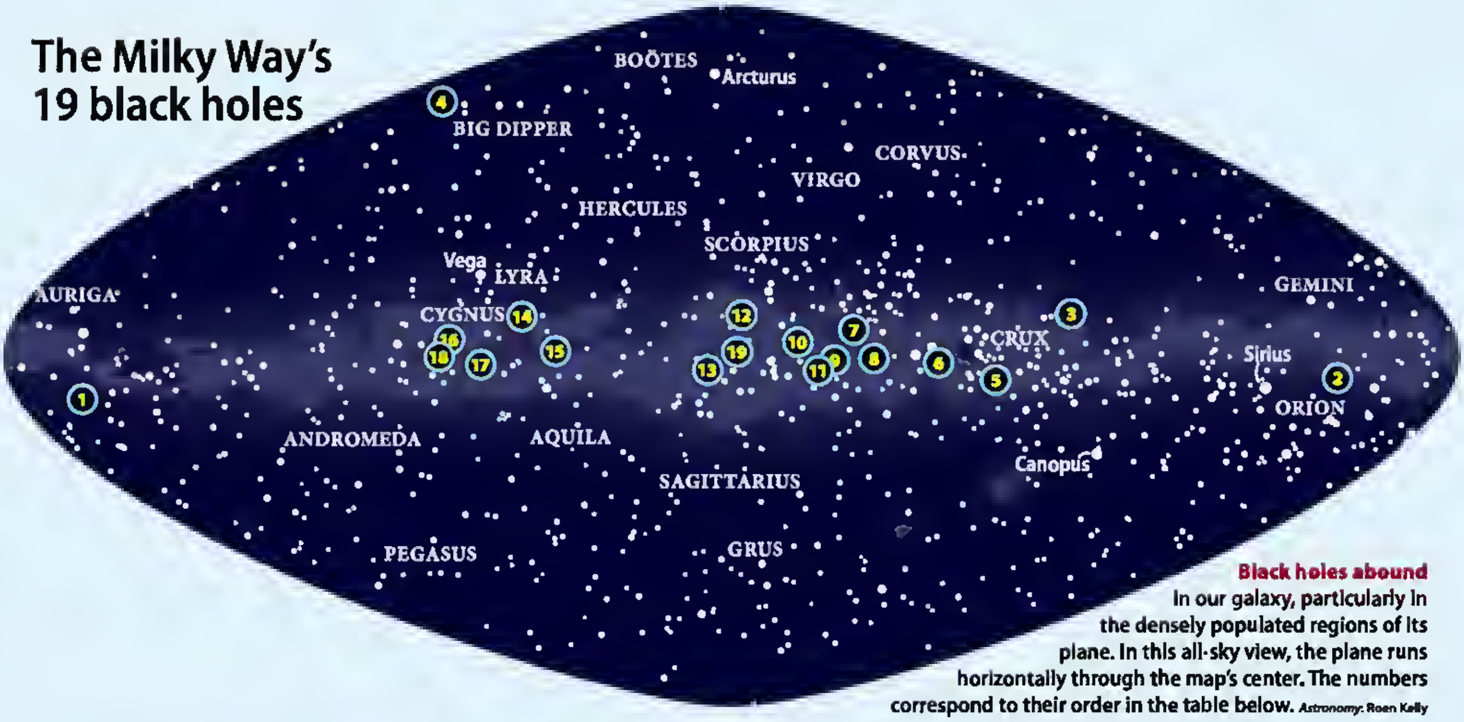
Several research teams have examined the Milky Way's largest globular, Omega Centauri, to do just that. In 2008, a group led by Eva Noyola of the Max Planck Institute for Extraterrestrial Physics in Germany reported a black hole weighing 40,000 solar masses. Just two years later, however, Jay Anderson and Roeland P. van der Marel of the Space Telescope Science Institute in Baltimore, Maryland, found no evidence for a black hole of that size. At this stage, neither side seems to be winning the debate.

A similar argument rages over the relatively nearby globular M15 in Pegasus. Some researchers claim the presence of an intermediate-mass black hole weighing about 4,000 Suns, while others find no such evidence. Earlier this year, Jay Strader of the Harvard-Smithsonian Center for Astrophysics and his colleagues announced that new observations show M15 can't have a black hole larger than 980 solar masses.

The beast in the middle

While strong evidence for intermediate-mass black holes is lacking, the same can't be said for their big brothers. Astronomers have found compelling signs for a supermassive black hole in the center of almost every large galaxy they have scrutinized, and the Milky Way is no exception. The core of our galaxy harbors an object called Sagittarius A* (pronounced A-star) — a black hole

The Milky Way's 19 black holes



Black holes abound in our galaxy, particularly in the densely populated regions of its plane. In this all-sky view, the plane runs horizontally through the map's center. The numbers correspond to their order in the table below. *Astronomy*: Roen Kelly

Number	Designation	R.A.	Dec.	Constellation	Spectral type	Magnitude	Period (hrs)	Distance (lys)	Type	Mass (Suns)
1	GRO J0422+32	4h21.7m	32°54'	Perseus	M4 V	13.2	5.1	8,000	Low-mass X-ray binary	4
2	A0620–00	6h22.7m	–0°21'	Monoceros	K4 V	11.2	7.8	3,400	Low-mass X-ray binary	11
3	GRS 1009–45	10h13.6m	–45°05'	Vela	K7 V	14.7	6.8	12,500	Low-mass X-ray binary	4
4	XTE J1118+480	11h18.2m	48°02'	Ursa Major	K5 V	12.3	4.1	5,800	Low-mass X-ray binary	7
5	GRS 1124–684	11h26.4m	–68°41'	Musca	K5 V	13.3	10.4	18,000	Low-mass X-ray binary	7
6	GS 1354–64	13h58.2m	–64°44'	Circinus	G IV	16.9	61.1	86,000	Low-mass X-ray binary	7
7	4U 1543–475	15h47.1m	–47°40'	Lupus	A2 V	14.9	26.8	24,500	Low-mass X-ray binary	9
8	XTE J1550–564	15h51.0m	–56°29'	Norma	K3 III	16.6	37.0	17,300	Low-mass X-ray binary	10
9	XTE J1650–500	16h50.0m	–49°58'	Ara	K4 V	?	7.7	8,500	Low-mass X-ray binary	4
10	GRO J1655–40	16h54.0m	–39°51'	Scorpius	F5 IV	14.2	62.9	10,000	Low-mass X-ray binary	6
11	GX 339-4	17h02.8m	–48°47'	Ara	?	—	42.1	20,000	Low-mass X-ray binary	at least 6
12	Nova Ophiuchi 77	17h08.2m	–25°05'	Ophiuchus	K5 V	15.9	12.5	33,000	Low-mass X-ray binary	7
13	Sagittarius A*	17h45.7m	–29°00'	Sagittarius	—	—	—	26,000	Supermassive	4 million
14	V4641 Sagittarii	18h19.4m	–25°24'	Sagittarius	B9 III	9	67.6	32,000	Low-mass X-ray binary	7
15	XTE J1859+226	18h58.7m	22°39'	Vulpecula	K0 V	15.3	6.6	20,500	Low-mass X-ray binary	5
16	GRS 1915+105	19h15.2m	10°57'	Aquila	K III	12.2	804	39,000	Low-mass X-ray binary	14
17	Cygnus X-1	19h58.4m	35°12'	Cygnus	O9.7 Iab	8.9	134.4	6,100	High-mass X-ray binary	15
18	GS 2000+251	20h02.8m	25°14'	Vulpecula	K5 V	18.2	8.3	6,500	Low-mass X-ray binary	7
19	V404 Cygni	20h24.1m	33°52'	Cygnus	K0 IV	12.7	155.3	8,000	Low-mass X-ray binary	12

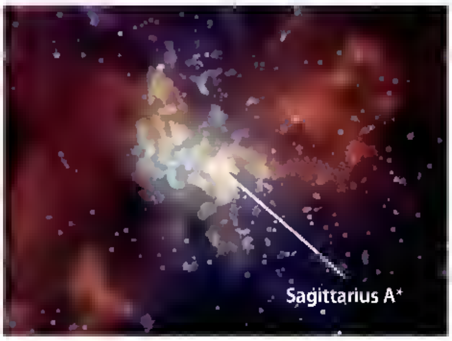
R.A. = Right ascension (2000.0); Dec. = Declination (2000.0); Spectral type and Magnitude are for the black hole's companion star; Period is the orbital period of binary systems in hours; Distance is estimated in light-years; Mass is approximated in solar masses

with about 4 million times the Sun's mass. It's the 19th confirmed black hole in the Milky Way, and it sits dead in the center.

The evidence takes several forms. First, intense radio waves and X-rays flow from an accretion disk that spans a region no bigger than our solar system. But the proof comes from careful tracking of the motions of stars as they orbit the central mass. It's the same method astronomers use to hunt for globular cluster black holes, but the huge size of the object in the Milky Way's heart makes these motions far easier to see. Analyzing the stellar orbits leads directly to the black hole's mass.

The count of black holes in our galaxy likely will continue to grow in the years ahead, but it never will outpace the flood of planet discoveries. The ability to find planets has reached the stage where it's surprising when a week goes by without a new detection. Black holes hide their identities much better, either behind the cloak of an event horizon or in isolation from other objects. Perhaps the biggest surprise in the study of our galaxy's black holes is that we've already found 19.

Watch a black hole devour a star at www.Astronomy.com/toc.



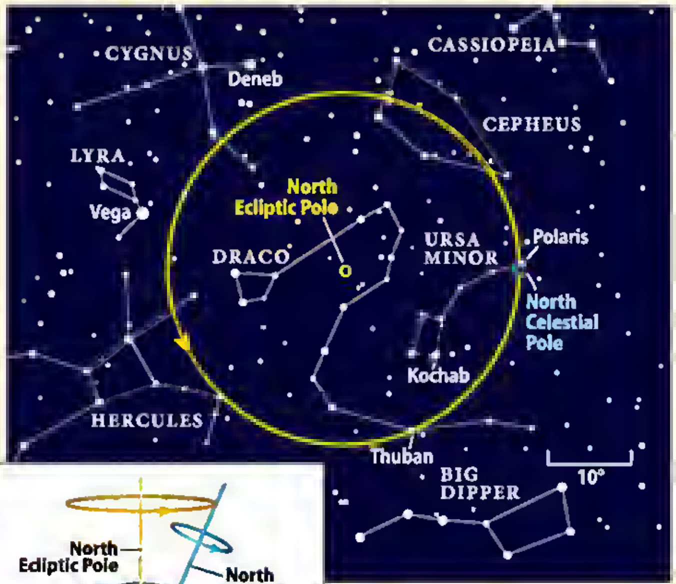
NASA/CXC/MIT/F. K. Baganoff, et al.

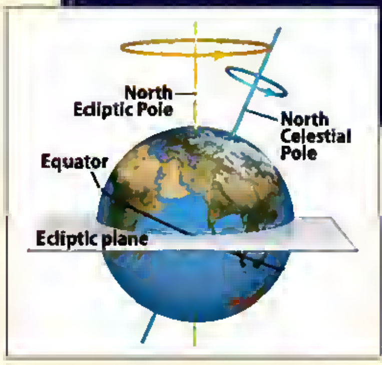
The supermassive black hole at our galaxy's heart is not a voracious eater. This X-ray image reveals lobes of hot gas extending a dozen light-years from the black hole (Sagittarius A*) but only a small glow for the black hole itself.

Astronomy's experts from around the globe answer your cosmic questions.

Determining direction

Q: What is the circle that Earth's axis traces out in its 26,000-year precession cycle? What bright stars would be close to it? — **Tim Boyle,** Nishinomiya, Japan





Earth's spin axis precesses and traces out a circle over about 26,000 years. The brightest star nearest the North Celestial Pole is known as the North Star. Because the axis points in a different direction over time, the identity of the "North Star" also changes.

A: As Earth orbits the Sun, it also spins about its axis in just less than 24 hours. Our planet exhibits other motions as well — the most dramatic of them is known as precession. You can see precession every time you spin a top. As the top begins to slow, it also starts to wobble on its axis. A gyroscope does exactly the same thing, and so does Earth. As a result, a line extending from Earth's North Pole slowly traces a large circle around the sky. It takes about 26,000 years to complete one precessional cycle.

In 1000 B.C., ancient mariners such as the Phoenicians had no convenient pole star to use for navigation. In the 5,000 to 6,000 years of recorded human history, Polaris (Alpha [α] Ursae Minoris) is a relative newcomer to the job of pole marker.

The sides of the great pyramids of Egypt align with the four cardinal directions. In the 19th century, explorers discovered a small shaft in the largest pyramid that pointed to the North Celestial Pole. **Four thousand years ago, Egyptian astronomers were using the star Thuban (Alpha Draconis) as their pole star.** As the centuries crept by, Thuban appeared to drift away from the North Celestial Pole. **Although it was never as close to the Celestial Pole as Thuban, Kochab (Beta [β] Ursae Minoris) served as the North Star around 2000 B.C.** At the height of the Roman Empire, there was no conspicuous North Star. Ancient travelers and seafarers had to use other methods to determine the direction north.

About 1,000 years ago, people began using Polaris as a standard for navigation. Alas, Polaris too will slip away from the Celestial Pole. In 14,000 years, the brilliant star Vega (Alpha Lyrae) will replace it. Vega is much brighter than Polaris, but it will never come as close to the Celestial Pole as the current North Star. At its best, Vega will be almost 10 Moon diameters away from that specific spot in the Northern Hemisphere. — **Raymond Shubinski,** Contributing Editor

LUNAR IMPACTS

Q: How deep are the craters on the Moon? — **Patricia Zavahir,** Colombo, Sri Lanka

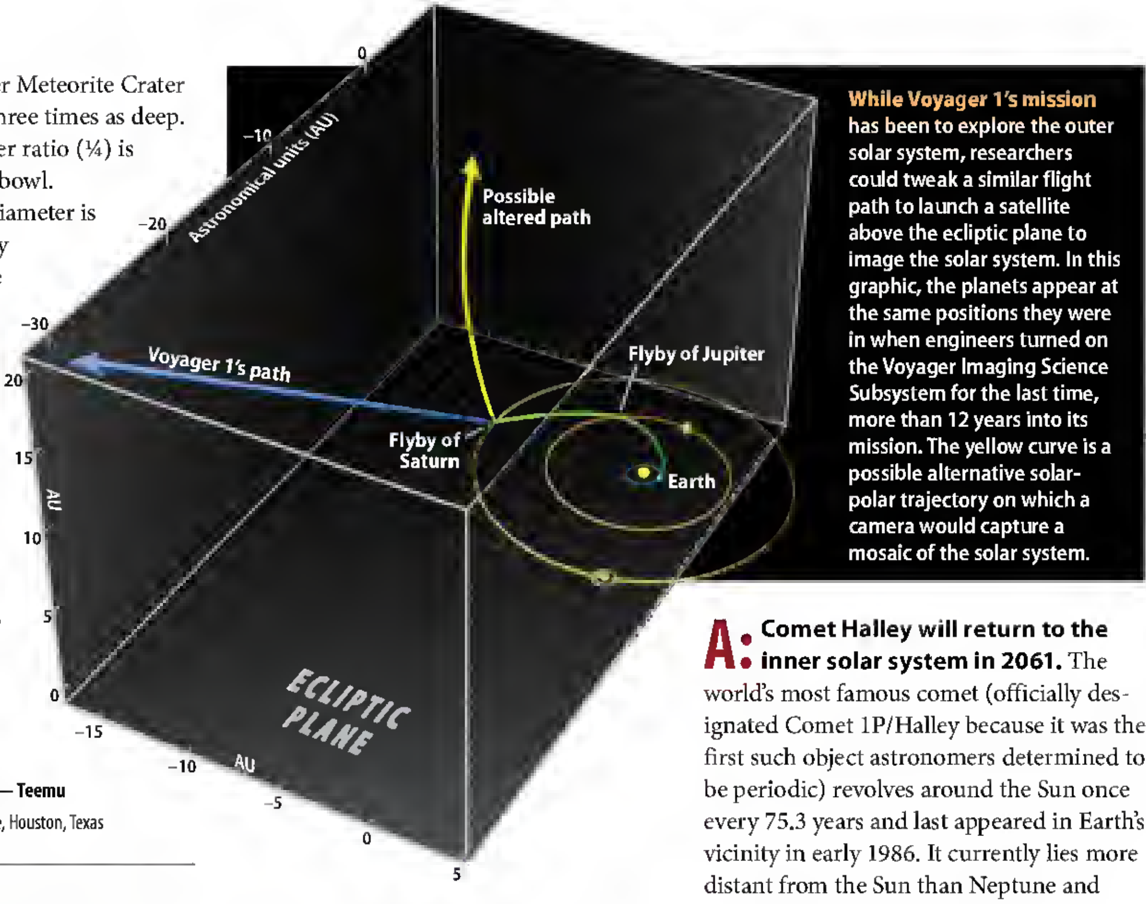
A: When the Sun is low on the lunar horizon, impact craters appear from Earth as dramatic, deep pits with uplifted, rugged rims. Although this appearance is slightly deceiving, lunar craters are quite prominent depressions. Planetary scientists usually define the depth of an impact crater as the distance from the crater rim to the crater floor. **Well-preserved large craters like Tycho (about 53 miles [85 kilometers] across), Copernicus (58 miles [93km] wide), and Aristarchus (25 miles [41km] in diameter) have rim-to-floor depths of about 15,700 feet (4,800 meters), 12,500 feet (3,800m), and 9,800 (3,000m), respectively.** If Denali (Mount McKinley) in Alaska, the highest mountain in North America measured from the base to the peak, were placed on the floor of Tycho, its highest point would rise slightly above the crater's rim.

In relative terms, however, **these large so-called "complex" craters are surprisingly shallow features. Their depths are only a small fraction, about 1/15 to 1/25, of their diameters. So these "deep pits" are actually shallower than dinner plates.**

In contrast, fresh craters smaller than about 9 to 12.5 miles (15 to 20km) in diameter have much higher depth-to-diameter ratios. A good example of these simple lunar craters is Linné. It has a diameter of 1.3 miles (2.2km) and a depth of 1,800 feet (550m) — about the same as the Statue of Liberty placed on top of the Empire State Building. To compare with the best example on Earth, Linné is about twice

the diameter of Barringer Meteorite Crater in Arizona, but almost three times as deep. Linné's depth-to-diameter ratio (¼) is similar to that of a soup bowl.

Because the Moon's diameter is small, its surface is highly curved, which makes the horizon extremely close. This further enhances the apparent flatness of larger craters to someone on the lunar surface. (If a visitor were 6.5 feet [2m] tall, the lunar horizon would be only about 1.6 miles [2.6km] away.) The Moon's curvature "sinks" the rims of larger craters beyond the horizon. A structure would need to rise very tall and be very close for it to look high. — **Teemu Öhman,** Lunar and Planetary Institute, Houston, Texas



While Voyager 1's mission has been to explore the outer solar system, researchers could tweak a similar flight path to launch a satellite above the ecliptic plane to image the solar system. In this graphic, the planets appear at the same positions they were in when engineers turned on the Voyager Imaging Science Subsystem for the last time, more than 12 years into its mission. The yellow curve is a possible alternative solar-polar trajectory on which a camera would capture a mosaic of the solar system. Astronomy: Roen Kelly, after John D. Anderson

THE FULL PICTURE

Q: Would it be possible to send a probe vertically above the solar system's plane to observe the entire solar system and capture a mosaic photo? How far would it need to go to get a complete photo of everything?
— **Ken Warner,** San Bernardino, California

A: Yes, this is possible. There are many ways to get out of the solar system's plane (called the ecliptic plane), but until an unusually large propulsion system is available, a flyby of Jupiter or Saturn is the best way to do it. The European/NASA Ulysses mission (launched in 1990) used a flyby of Jupiter to reach a six-year period in an orbit over the Sun's north and south poles. However, to reach large distances above or below the ecliptic plane, the best way to gain orbital velocity is via a flyby of Jupiter and then a flyby of Saturn to throw the spacecraft out of the ecliptic plane. The Voyager 1 trajectory illustrates this technique (see image at upper right).

Voyager 1 launched September 5, 1977, on a direct 546-day trajectory between Earth and Jupiter. The Jupiter flyby placed the craft on a 618-day path to Saturn, and the Saturn flyby threw the craft out of the ecliptic plane on an escape trajectory. More than 12 years after launch, with the craft 40 astronomical units (AU, where 1 AU is the average Sun-Earth distance) from the Sun, engineers pointed Voyager 1's camera system back at the solar system. From a position 22 AU above the ecliptic plane, the craft recorded some impressive images, including the famous "pale blue dot" photo of Earth. Voyager 1's Saturn encounter could have been modified such that the final Voyager orbit would have passed over the poles of the Sun with an orbital period of 181 years.

A typical planetary camera captures a 4° or 5° field. **To get the entire solar system in one field of view would mean the craft would have to be 90° to the ecliptic plane with a 75° field of view; this would take 31 years after its Saturn encounter (provided it follows a modified Voyager 1 trajectory). At the point when the craft is 90° to the plane, it would be 38.4 AU above it.** — **John D. Anderson,** NASA's Jet Propulsion Laboratory (retired), Pasadena, California

VISITORS FROM BEYOND

Q: When will Comet Halley next pass near Earth? Are there any other comets that will come close enough to our planet that people in the United States can see it at night?
— **James Morris,** Stockton, California

A: Comet Halley will return to the inner solar system in 2061. The world's most famous comet (officially designated Comet 1P/Halley because it was the first such object astronomers determined to be periodic) revolves around the Sun once every 75.3 years and last appeared in Earth's vicinity in early 1986. It currently lies more distant from the Sun than Neptune and Pluto and is nearing the far point of its orbit, which it will reach in 2023.

We probably won't have to wait half a century to see another bright comet. Unfortunately, astronomers can't tell us when the next great one will appear. Halley is the only short-period comet that regularly becomes bright enough to be obvious with unaided eyes. The most spectacular of these dust-rich balls of frozen gas are making their initial trips through the inner solar system. As their ices are exposed to intense sunlight for the first time, they erupt with activity and often grow long tails.

The list of dazzling newcomers since Halley last appeared in Earth's sky includes C/1995 O1 (Hale-Bopp), C/1996 B2 (Hyakutake), and C/2006 P1 (McNaught). Over the past few centuries, Earth has averaged roughly one bright comet every decade. So, expect to see at least a few more before Halley makes its next foray into the inner solar system — we just can't tell you when they will arrive. — **Richard Talcott,** Senior Editor

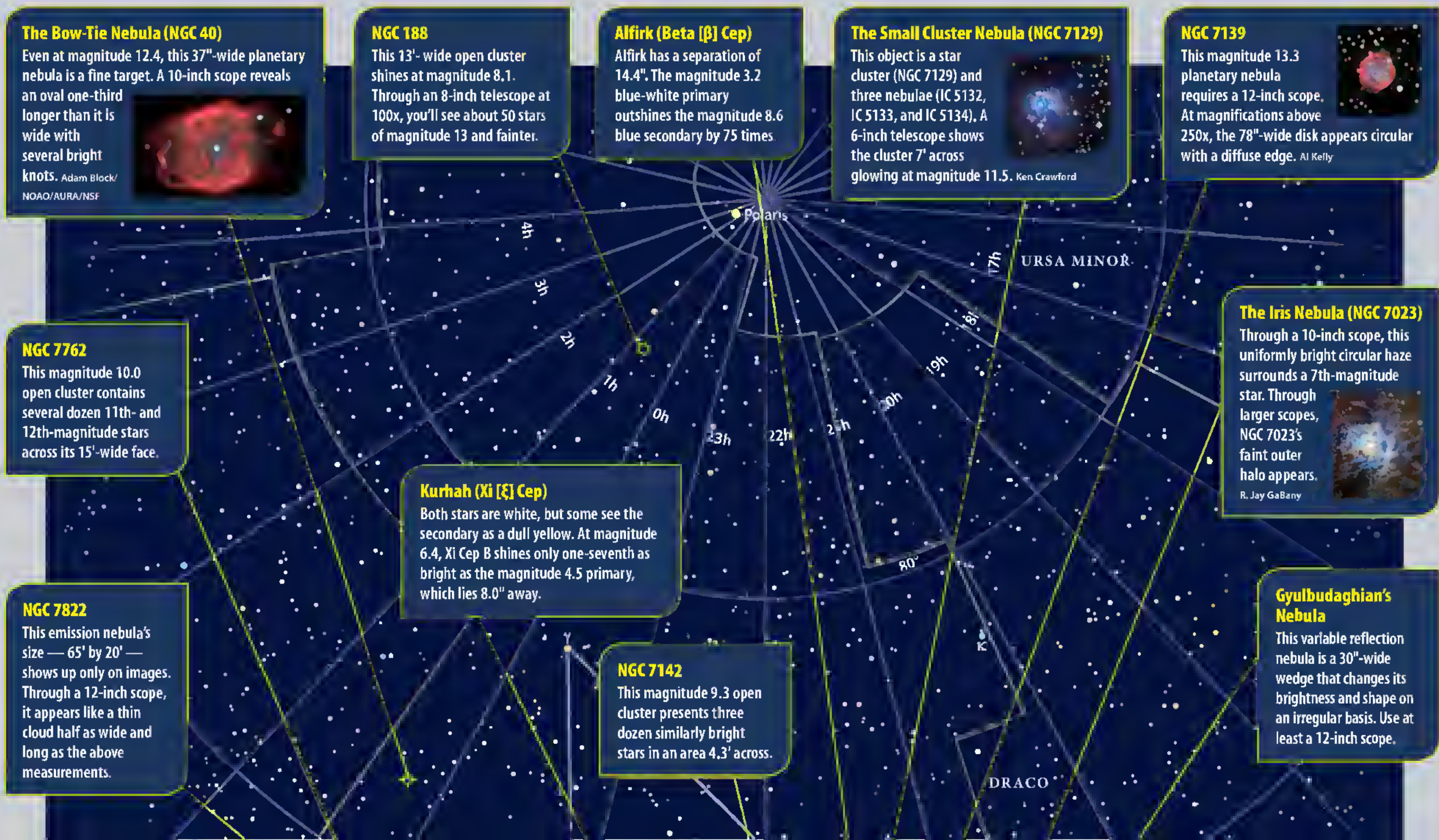
Send your questions via email to: **askastro@astronomy.com**; or write to **Ask Astro, P. O. Box 1612, Waukesha, WI 53187.** Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

Wander the **wonders** of the **King's constellation**

Cepheus contains enough star clusters, nebulae, and galaxies to keep you observing a long time. **by Michael E. Bakich**

THE CONSTELLATION CEPHEUS THE KING lies high in the northern sky. Because the Milky Way passes through much — but not all — of this star pattern, you'll find a wide variety of deep-sky objects here. Take this chart to your next observing session and use it to locate 25 of my personal favorites. I'm sure you'll agree that it's worth devoting some quality time to Cepheus' crown jewels.

Michael E. Bakich *is an* Astronomy *senior editor and an observational "completist" who likes seeing everything a constellation has to offer.*



The Bow-Tie Nebula (NGC 40)
Even at magnitude 12.4, this 37"-wide planetary nebula is a fine target. A 10-inch scope reveals an oval one-third longer than it is wide with several bright knots. Adam Block/NOAO/AURA/NSF

NGC 188
This 13'-wide open cluster shines at magnitude 8.1. Through an 8-inch telescope at 100x, you'll see about 50 stars of magnitude 13 and fainter.

Alfirk (Beta [β] Cep)
Alfirk has a separation of 14.4". The magnitude 3.2 blue-white primary outshines the magnitude 8.6 blue secondary by 75 times.

The Small Cluster Nebula (NGC 7129)
This object is a star cluster (NGC 7129) and three nebulae (IC 5132, IC 5133, and IC 5134). A 6-inch telescope shows the cluster 7' across glowing at magnitude 11.5. Ken Crawford

NGC 7139
This magnitude 13.3 planetary nebula requires a 12-inch scope. At magnifications above 250x, the 78"-wide disk appears circular with a diffuse edge. Al Kelly

NGC 7762
This magnitude 10.0 open cluster contains several dozen 11th- and 12th-magnitude stars across its 15'-wide face.

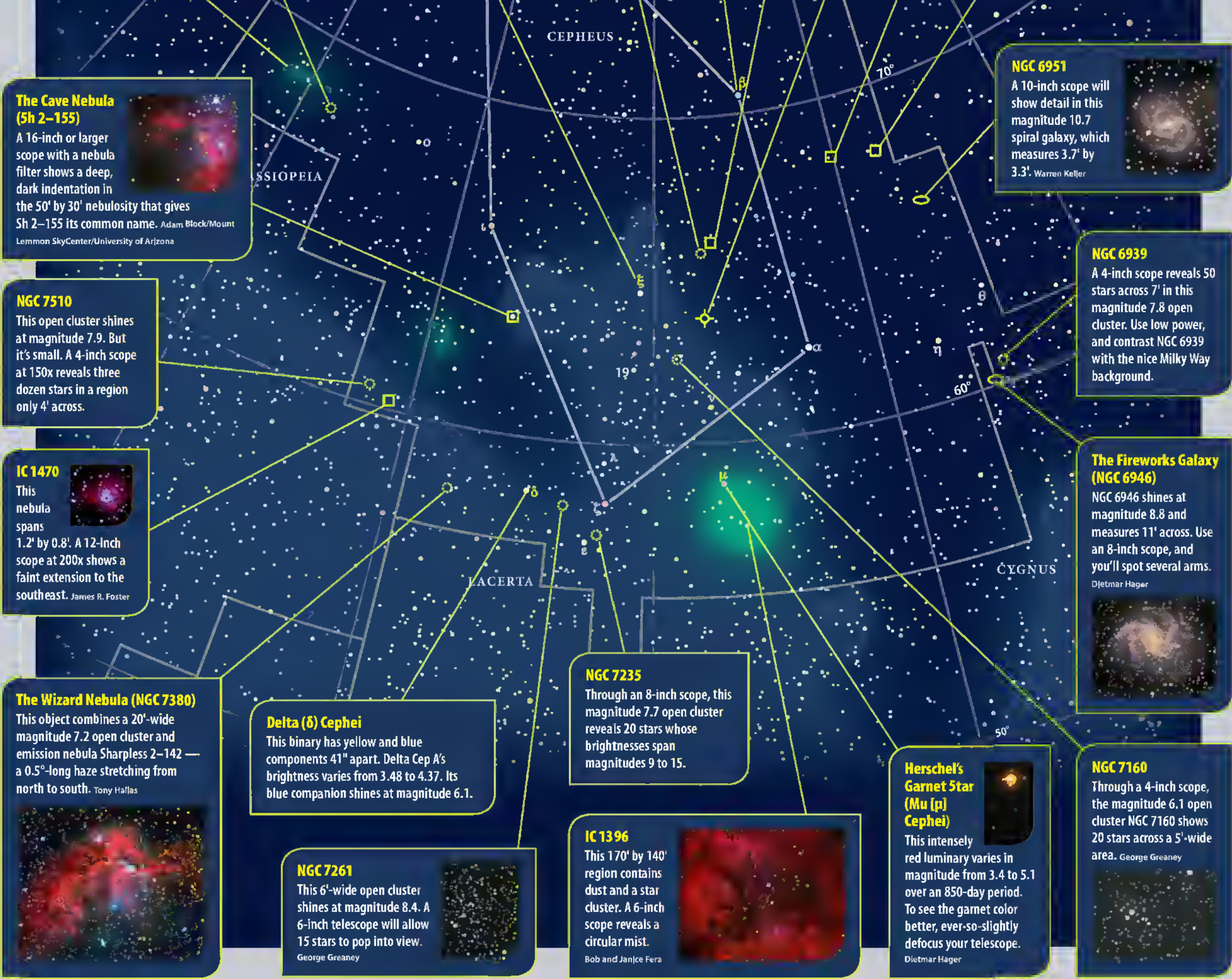
The Iris Nebula (NGC 7023)
Through a 10-inch scope, this uniformly bright circular haze surrounds a 7th-magnitude star. Through larger scopes, NGC 7023's faint outer halo appears. R. Jay GaBany

Kurhah (Xi [ξ] Cep)
Both stars are white, but some see the secondary as a dull yellow. At magnitude 6.4, Xi Cep B shines only one-seventh as bright as the magnitude 4.5 primary, which lies 8.0" away.

NGC 7822
This emission nebula's size — 65' by 20' — shows up only on images. Through a 12-inch scope, it appears like a thin cloud half as wide and long as the above measurements.

NGC 7142
This magnitude 9.3 open cluster presents three dozen similarly bright stars in an area 4.3' across.

Gyulbudaghian's Nebula
This variable reflection nebula is a 30"-wide wedge that changes its brightness and shape on an irregular basis. Use at least a 12-inch scope.



Star chart: *Astronomy*: Richard Talcott and Roen Kelly

The Cave Nebula (Sh 2–155)
A 16-inch or larger scope with a nebula filter shows a deep, dark indentation in the 50' by 30' nebulosity that gives Sh 2–155 its common name. Adam Block/Mount Lemmon SkyCenter/University of Arizona

NGC 7510
This open cluster shines at magnitude 7.9. But it's small. A 4-inch scope at 150x reveals three dozen stars in a region only 4' across.

IC 1470
This nebula spans 1.2' by 0.8'. A 12-inch scope at 200x shows a faint extension to the southeast. James R. Foster

The Wizard Nebula (NGC 7380)
This object combines a 20'-wide magnitude 7.2 open cluster and emission nebula Sharpless 2–142 — a 0.5°-long haze stretching from north to south. Tony Hallas

Delta (δ) Cephei
This binary has yellow and blue components 41" apart. Delta Cep A's brightness varies from 3.48 to 4.37. Its blue companion shines at magnitude 6.1.

NGC 7261
This 6'-wide open cluster shines at magnitude 8.4. A 6-inch telescope will allow 15 stars to pop into view. George Greaney

NGC 7235
Through an 8-inch scope, this magnitude 7.7 open cluster reveals 20 stars whose brightnesses span magnitudes 9 to 15.

IC 1396
This 170' by 140' region contains dust and a star cluster. A 6-inch scope reveals a circular mist. Bob and Janice Fera

Herschel's Garnet Star (Mu [μ] Cephei)
This intensely red luminary varies in magnitude from 3.4 to 5.1 over an 850-day period. To see the garnet color better, ever-so-slightly defocus your telescope. Dietmar Hager

NGC 6951
A 10-inch scope will show detail in this magnitude 10.7 spiral galaxy, which measures 3.7' by 3.3'. Warren Keller

NGC 6939
A 4-inch scope reveals 50 stars across 7' in this magnitude 7.8 open cluster. Use low power, and contrast NGC 6939 with the nice Milky Way background.

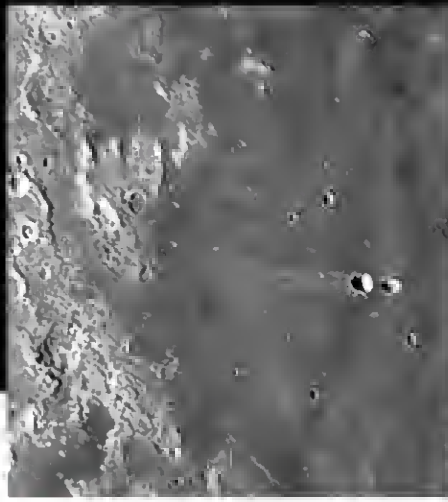
The Fireworks Galaxy (NGC 6946)
NGC 6946 shines at magnitude 8.8 and measures 11' across. Use an 8-inch scope, and you'll spot several arms. Dietmar Hager

NGC 7160
Through a 4-inch scope, the magnitude 6.1 open cluster NGC 7160 shows 20 stars across a 5'-wide area. George Greaney

Moon-watching

You should observe the **Full Moon!**

Mountains and lava plains, rays, and a hint of color invite exploring a bright Moon. **by Michael E. Bakich**



Perhaps the oddest ray system on the Moon originates at the craters Messier and Messier A.

Observer 1: "It's clear. Let's set up the scope."
Observer 2: "Nah. It's Full Moon."
Observer 1: "So, we'll look at the Moon."
Observer 2: "Are you nuts?"

I'm betting that if you haven't had this conversation, you've gone through the gist of it in your mind. Observe at Full Moon? Observe what, exactly? The Moon's intense light scatters through the sky, essentially eliminating every deep-sky object that's not a double star. And you certainly don't observe the Moon when it's Full because that's when the Sun lies highest in its sky on the part facing us, killing all details.

Not so fast. Believe it or not, several of our natural satellite's features are at their best when its shape is roundest. That's because in addition to formations that cast shadows (like mountains and crater walls), the Moon also contains albedo features, which depend on differences in reflectivity and color. (Oh, yes. Luna's surface displays a range of subtle colors.) Albedo features don't cast shadows under any lighting.

Three types of features are especially great to observe when Earth's nearest neighbor hangs like a ripe honeydew melon in the night sky. Remember to let the Moon rise as much as you can so you're looking through less of Earth's image-distorting atmosphere. Also note that if the view is uncomfortably bright, many manufacturers sell neutral density filters, which reduce the amount of light reaching your eyes but not change it in any other way.

Explore the seas

Early lunar observers dubbed the large, flat expanses visible to the eye *maria* (Latin for "seas") because they look like dark water-filled basins. Today we know that, rather than water, these large depressions contain vast solidified flows of lava made of basalt.

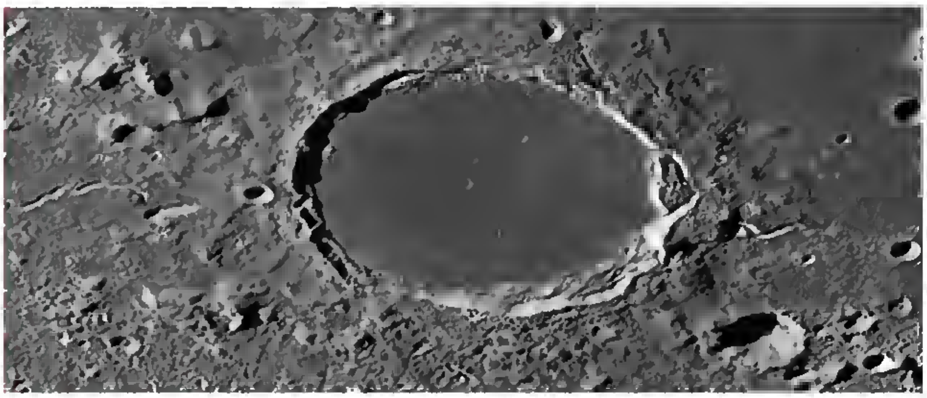
The lava on the floors of the maria appears much darker than the surrounding highlands, which are mostly anorthosite. That rock contains between 90 and 100 percent of the reflective mineral plagioclase feldspar. The contrast between the maria and the highlands is highest at Full Moon.

While Earth basalt tops out at about 14 percent iron, on the Moon that percentage can reach 22 percent. Likewise, basalt has a maximum of 2 percent of the mineral titanium dioxide (TiO_2) on Earth, whereas lunar basalt can contain up to 13 percent TiO_2. Iron and titanium are dark materials and contribute to the overall murky appearance of the maria.

Furthermore, because different lava flows have different concentrations of these substances, the floors of the maria reflect different percentages of light. You can prove this to yourself by looking at the Moon the next time it's Full. Even your unaided eyes will show that some maria are slightly darker than others. For example, take a look at the three connected maria on the Moon's eastern side: **Mare Serenitatis**, **Mare Tranquillitatis**, and **Mare Fecunditatis**. Each of them appears darker than either **Mare Imbrium** or **Oceanus Procellarum** on the western half.

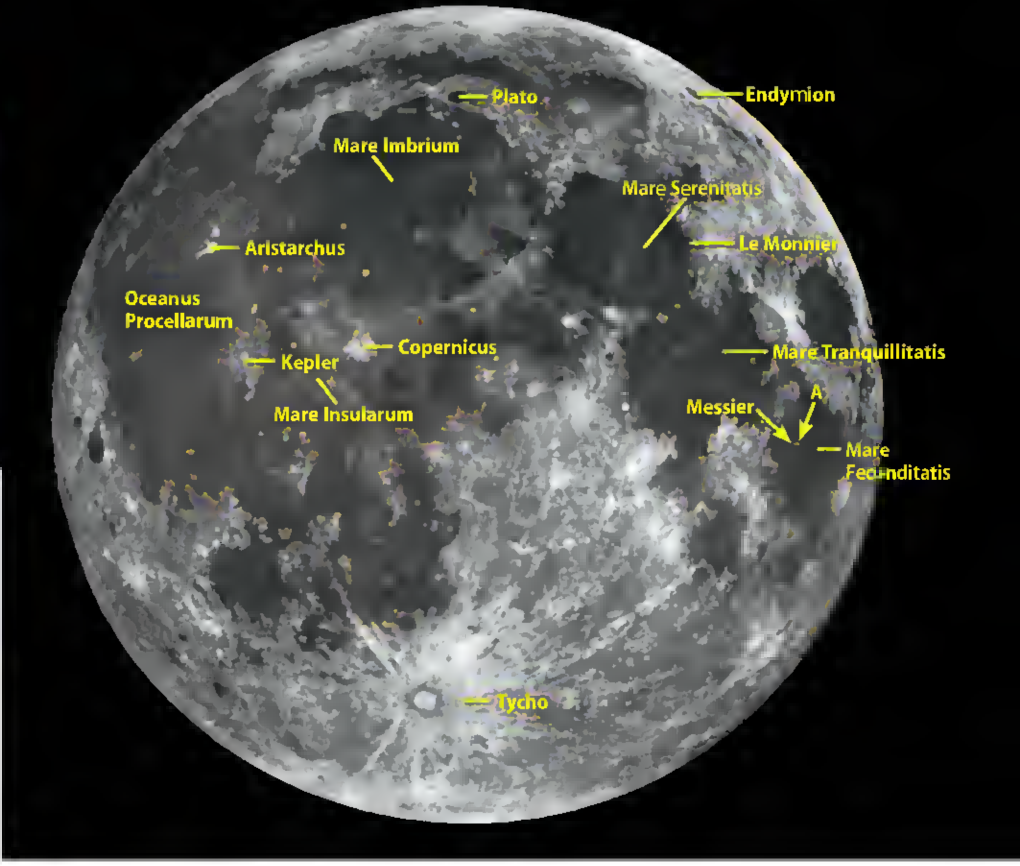
To see bright and dark areas within a single mare, point your telescope at Mare Serenitatis. Its center looks lighter than its edges. The differences in composition are because the two regions have different ages. The outer areas date from between 3.8 and 3.85 billion years ago while the center region may have formed as recently as 3.2 billion years ago.

The Moon also features a few craters with ultra-dark lava-covered floors, and these stand out best at Full Moon. The prime example is **Plato** Crater, which



Plato Crater's floor is so dark that early observers called it the "Greater Black Lake." Dave Tyler

Michael E. Bakich *is an* Astronomy *senior editor and author of* 1,001 Celestial Wonders to See Before You Die *(Springer, 2010).*



Numerous lunar features are visible when the Moon is Full. This image corresponds to a "naked-eye" view with north at the top and contains all boldface features in this story. Lick Observatory

Lunar directions

It's easy to determine the Moon's northern and southern halves because they correspond to those directions in our sky. Figuring out east and west, however, is not so intuitive.

In 1961, the International Astronomical Union adopted the same system of directions for the Moon as that used on Earth. This means an observer on either world sees the Sun rise in the east and set in the west. So, when we look at the Moon from the Northern Hemisphere, the eastern half (the portion lit at First Quarter) is to the right and the western half (Last Quarter) lies to the left.

astronomers as early as the 17th century referred to as the "Greater Black Lake."

Like the maria, Plato filled with dark lava approximately 3.84 billion years ago. Other craters with dark floors are **Le Monnier** and **Endymion**.

During Full Moon, compare Plato with **Aristarchus** Crater, our satellite's brightest such feature. It appears so dazzling because it's young — only 450 million years old.

When you're viewing lunar features with similar compositions, older ones will appear darker because the process of space weathering (by the solar wind, cosmic rays, and micrometeorites) has affected them longer. In Aristarchus' case, the material thrown out by the impact that formed it hasn't darkened much.

Trace lunar rays

Sometimes a dark surface covers lighter material. If, as has happened millions of times, a meteor hits the Moon, the impact can splash some of what's underground across the landscape. And the bigger the meteor, the longer and brighter the splash. Astronomers call such ejecta "rays." Most resemble the spokes of a wheel and extend for many times their crater's diameter. And Full Moon is the best time to view them.

Tycho Crater has the most extensive ray system. Some of its spokes reach as far as 930 miles (1,500 kilometers) from the impact point. Tycho and its ray system are so bright that you even can see them when only earthshine (sunlight reflected from Earth to the Moon's night portion) illuminates the thin crescent Moon.

The crater with the next most prominent rays is **Copernicus**. Because it formed 810 million years ago, researchers struggled for decades to explain why its rays — which spread out for 500 miles (800km) — remain bright. Current theory suggests that the crater's impactor excavated bright highland material and sprayed it across the dark surface of **Mare Insularum.**

Copernicus, along with **Kepler** Crater to its west and Aristarchus to Kepler's northwest, form a right triangle of rayed craters on Oceanus Procellarum that merits your attention. A low-power eyepiece in your scope reveals rays from each overlapping those from the other two and bright pairs of rays connecting all three.

You'll find a unique ray system in Mare Fecunditatis associated with two small craters — **Messier** and **Messier A** — that you simply must observe. Two straight, slightly diverging rays more than 60 miles (100km) long extend westward from Messier A, leading most observers to describe the scene as "comet-like."

Here a meteor first formed Messier and then bounced to form Messier A. The oblong shapes of the craters and the direction of the rays indicate a low impact angle.

Look for the colors

While it's true that the Moon doesn't display a vivid rainbow of hues, you can use color filters to enhance what differences exist. The basalt in the maria, for example, appears a bit bluer than the anorthosite in the highlands. So, to darken the maria and enhance the contrast between them and the highlands, try a red filter.

Note: Several manufacturers make filters in different shades, for example, light-red, medium-red, and red. Because you're observing the Full Moon, use the darkest filter. It will have the added benefit of cutting down our satellite's light.

To get slightly better views of the rays, try light- or medium-green or yellow filters. Depending on the color sensitivity of your eyes, one of these filters may enhance the contrast between the material splashed out when the meteor created the crater and the darker surface rock.

So don't be too hasty to cross off the dates, as the song goes, "when the Moon hits your eye like a big pizza pie." To many amateur astronomers, that's observing!

Find more lunar features to target at www.Astronomy.com/toc.

Astronomy magazine 2012 Star Products

Astronomy's third annual STAR PRODUCTS

Thomas V. Davis

Get ready ta agle same amazing equipment as we hanar the **35 best** *telescapes, cameras, and accessaries praduced in the past year.* **by Phil Harrington**

It's time again to survey the amateur astronomy marketplace and announce our 2012 *Astronomy* Star Products awards. The 35 winners, listed here alphabetically by manufacturer, represent the best and most innovative pieces of astro-equipment to come along in recent memory. Some are high-end, no-compromise products while others are low-cost items that offer excellent value.

1 AG Optical Newtonian astrographs

Catering to the growing trend in fast astrographs, AG Optical offers 8-, 10-, 12.5-, and 16-inch Newtonian reflectors designed specifically with astroimagers in mind. An incorporated optical corrector ensures pinpoint stars over a 50-millimeter-wide field, large enough for most of today's CCD cameras. Each scope incorporates a carbon-fiber tube that is lightweight as well as stiff and stable at all temperatures.

2 Astra Dame 2400

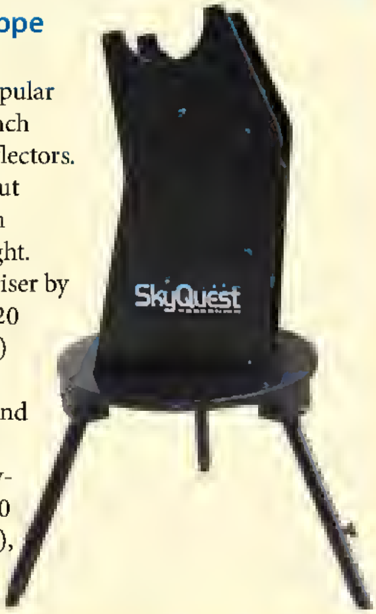
For Dobsonian owners, most commercial observatory domes are impractical because of the height of their walls. Astro Domes, however, designed its models to sit on the ground, offering unobstructed viewing from zenith to horizon. Each rotates smoothly on nylon wheels, while the shutter operates off a 12-volt battery. Sizes range from the newest 2.4-meter (7.9 feet) model up to 9 meters (29.5 feet) in diameter.

3 *Astranamy Magazine: The Complete Callection*

How has the science and hobby of astronomy changed over the past nearly four decades? The best way to see for yourself is to scan back issues of *Astronomy*. And now, you can e-thumb your way through them all on your computer with this new compilation DVD that includes every issue from August 1973 (the first) right up through December 2010. Plus you get every issue from former sister publications *Deep Sky* and *Telescope Making*, all the magazine's special issues, and a complete history of *Astronomy* magazine.

Phil Harrington *is an* Astronomy *contributing editor and author of* Cosmic Challenge: The Ultimate Observing List for Amateurs *(Cambridge University Press, 2010).*

4 Astronomy-Shoppe The DobStand



Some of today's most popular telescopes are 6- to 10-inch Dobsonian-mounted reflectors. They offer great value, but using them can be a pain because of their low height. Enter The DobStand, a riser by Astronomy-Shoppe. At 20 inches (50.8 centimeters) across, The DobStand replaces the scope's ground board. Simply adjust the three aluminum legs anywhere between 15 and 20 inches (38.1 and 50.8cm), and your telescope is ready to go.

5 BinaryRivers *BackYardEOS*

BinaryRivers' automated image-acquisition software for Windows operating systems takes the guesswork out of camera manipulation. It lets users frame, focus, and control the exposures of their Canon digital single-lens reflex cameras in real time all from the convenience of their computer screen. *BackYardEOS* also integrates with autoguiding software to automate dithering between exposures as well as to control ASCOM-compliant focusers.

6 Catseye Deluxe Triplepack XLK

Nothing ruins the view through a telescope more than improperly aligned optics. By design, Newtonian reflectors are especially susceptible to this problem because of the way the primary mirror connects to the telescope's tube. Recently, Catseye added a deluxe 2-inch three-tool collimation kit for scopes with f/ratios between f/3.5 and f/6 to its product lineup. The kit includes a Cheshire eyepiece, adjustable-length sight tube, two-pupil autocollimator, a template and two spots for center-spotting the primary mirror, a bright red LED clip light, and a comprehensive set of instructions — all in a custom carrying case.

7 Celestron CPC Deluxe 800 HD

Celestron continues to refine the Schmidt-Cassegrain design the company pioneered half a century ago. The CPC Deluxe 800 HD Computerized Telescope features optics that produce crisp images edge to edge as well as the company's premium StarBright XLT coatings. Celestron's NexStar computer-control technology provides fast and easy alignment and a 40,000-object database. The redesigned CPC mount includes a large brass gear and matching stainless steel worm gear. Add to that All-Star polar alignment, which allows you to choose any bright star, and you have an instrument sure to stand the test of time.

8 Celestron Nightscape CCD Camera

It's amazing how inexpensive high-quality CCD cameras have become. Celestron's new Nightscape is a 10.7-megapixel color camera whose backbone is Kodak's KAI-10100 color chip. Integrated thermoelectric cooling reduces the level of thermal noise that plagues all imaging sensors. It also comes with *AstroFX* software for Windows, which can control the camera, capture images, and process the results.

9 Celestron SkyProdigy 6

Celestron unveiled two new models in its SkyProdigy lineup at the 2012 Consumer Electronics Show in Las Vegas, Nevada. Like previous telescopes in the series, the SkyProdigy 6 Schmidt-Cassegrain features the company's innovative StarSense Technology. After you set up the scope, a built-in camera compares the sky to a database of more than 4,000 objects and aligns the instrument's computerized go-to aiming system in less than three minutes.

10 DobSTUFF Makeover kits

Do you have a stock Dobsonian-mounted Newtonian reflector that you would like to improve with better componentry? Or maybe you've always wanted to make a telescope yourself but lack the skills or the woodworking tools needed for the job. DobSTUFF's Makeover kits contain what you need to turn your off-the-shelf telescope into a customized instrument that's as great to look at as it is to use.

11 Explore Scientific 9mm 120° Series Argon-Purged Waterproof Eyepiece

Looking for the eyepiece with the largest apparent field of view? You'll find it with Explore Scientific's 9mm 2" eyepiece. Flaunting a highly corrected 120° apparent field, this masterpiece produces sensational views of deep-sky objects. Every lens element has enhanced multilayer deposition coatings and sits securely in an argon-purged barrel to guard against fungal growth and dust intrusion.

12 Explore Scientific David H. Levy Comet Hunter

Explore Scientific's 6-inch Maksutov-Newtonian telescope delivers incredible sharpness across a broad field of view. Imagine squeezing the full length of Orion's Sword into a single eyepiece field with edge-to-edge pinpoint star images. That's what you can do when you use this scope with the included 30mm eyepiece. A high-quality focuser, a finder scope, and a carbon-fiber tube complete this impressive package.

13 Farpoint Astro Armour Cases

Astronomers love to bring their telescopes and cameras on vacation with them, but traveling with such delicate instruments can be a harrowing experience. Farpoint smooths out some of the bumps with its heavy-duty Astro Armour Cases. These rugged packages feature foam interiors that you can customize to the exact size and shape of eyepieces, binoculars, cameras and even small telescopes.

14 Hands on Optics AstroTelescopes 102mm (4") f/11 Refractor

Traditional long-focal-length refractors are famous for their sharp planetary and double-star images. The AstroTelescopes 102mm refractor made by Kunming United Optics in China delivers just that at a remarkably low price. A dual-speed, fully rotatable 2" Crayford focuser; an aluminum tube; and a pair of mounting rings all come standard. Place this 12-pound (5.4 kilograms) scope on a mount of your choice, and you will enjoy great views for years.

15 Hubble Optics 16" f/4.5 Premium Ultra Light Dobsonian System

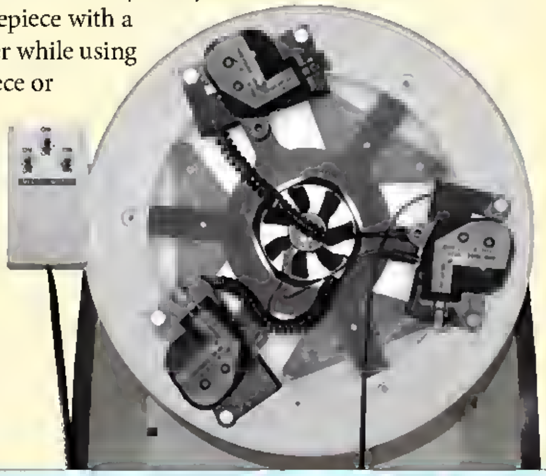
Many observers need to travel far from home in order to enjoy dark skies. And hauling a telescope with a large aperture in a small car can often prove daunting. But Hubble Optics' 16-inch f/4.5 Dobsonian-mounted Newtonian makes the effort much less intense. Fully assembled, the UL16 weighs only about 60 pounds (27.2 kilograms) thanks in part to its mirror, which incorporates the company's compact open-core "sandwich" design.

16 Innovations Foresight ONAG

For astroimagers, guiding long exposures has always been a challenge. The ONAG on-axis guider makes that task a little easier. Inside, a specially coated mirror diverts light 45° through a side port to the imaging camera. Near-infrared light, however, passes through the mirror and then through a back port, where an autoguider sits. That means you can guide on objects within the same field of view you are imaging, including the target itself.

17 JMI Telescopes ColliMotor

Amateur astronomers dislike collimating a Newtonian reflector because the process usually involves running between the eyepiece at the front of the telescope and the mirror cell at the back. The Colli-Motor retrofit kit from JMI lets you adjust the mirror at the eyepiece with a hand-held controller while using a collimation eyepiece or laser. JMI makes the ColliMotor for Meade's 10- to 16-inch Lightbridge, as well as Orion's SkyQuest XT10 and XT12 scopes.



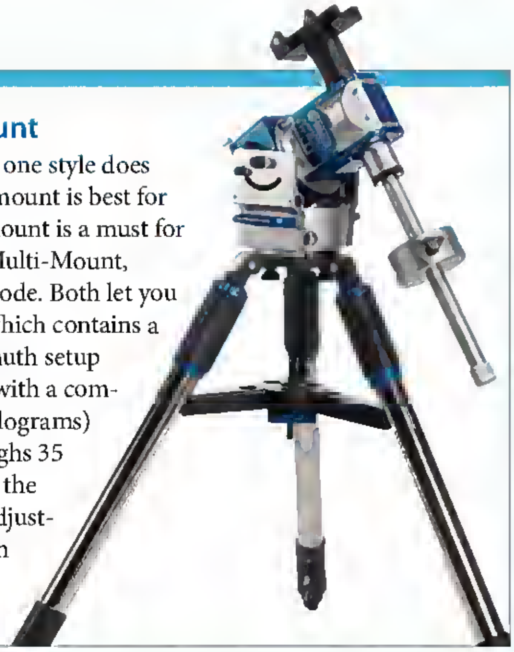
18 Lunt Solar Systems LS35T

This Hydrogen-alpha scope provides a great way to keep track of solar prominences and flares. The 1.4-inch (35mm) refractor's single-stack filtration system has a bandpass of less than 0.75 angstrom, making it ideal for visual observations. The LS35T includes a base for attachment to a tripod and a foam-lined case. For an extra $150, the deluxe version adds a Tele Vue Sol Searcher finder and a 10mm eyepiece.

19 Meade Series 5000 HD-60 eyepieces

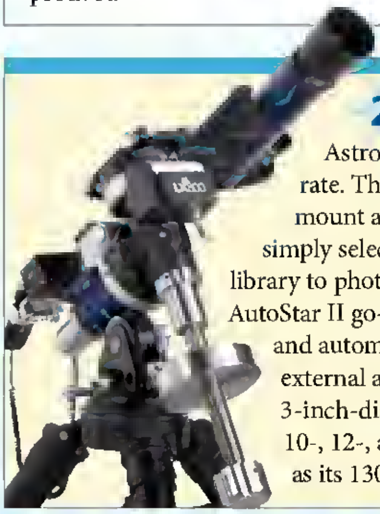
Combining a 60° apparent field of view, 17mm of eye relief, an adjustable eyeguard, and a price tag under $80, Meade's new HD-60 eyepieces are a great deal. Focal lengths include 4.5mm, 6.5mm, 9mm, 12mm, 18mm, and 25mm. If you must wear eyeglasses when you observe but cannot afford to spend exorbitant amounts on premium eyepieces, the HD-60 series offers an excellent choice.

20 Meade LX80 Multi-Mount



When it comes to telescope mounts, one style does not suit all models. An alt-azimuth mount is best for quick sessions while an equatorial mount is a must for astroimaging. Enter Meade's LX80 Multi-Mount, which you can configure in either mode. Both let you take advantage of its go-to system, which contains a 30,000-object database. The alt-azimuth setup even lets you mount two telescopes with a combined weight up to 75 pounds (34 kilograms) at once. The LX80 Multi-Mount weighs 35 pounds (15.9kg), and the tripod tips the scales at 31.5 pounds (14.3kg). An adjustable stainless-steel tripod with 2-inch legs completes this multipurpose product.

21 Meade LX800 Mount



Astrophotography continues to evolve at a furious rate. Thanks to Meade's new LX800 German equatorial mount and its integrated StarLock system, you can now simply select a target from the more than 144,000-object library to photograph. The mount, which uses the company's AutoStar II go-to system, then slews to the object, locks onto it, and automatically corrects tracking errors without any external assistance. The adjustable-height tripod features 3-inch-diameter legs. Look for the LX800 with Meade's 10-, 12-, and 14-inch ACF catadioptric telescopes, as well as its 130mm apochromatic refractor.

22 Moonglow Technologies All Sky Cam

There's always a lot going on over our heads. To follow the action, Moonglow introduced the All Sky Cam. It gives a full-color horizon-to-horizon view of either the daytime or nighttime sky. Watch clouds and the Sun cross the sky during the day, and stars, the Moon, planets, meteors, and aurorae at night, all from any television or Windows computer with optional software.

23 Optics Planet Bushnell ARES 5-inch Compact Truss Tube Dobsonian

Compact Dobs, like this 5-inch f/5 Newtonian reflector made exclusively for Optics Planet by Bushnell, are great traveling companions. To make the 14-pound (6.4 kilograms) ARES 5 even more compact, it collapses to just 16 inches (41 centimeters) long. To observe, just unlock and slide out the two truss tubes, secure them, and the scope is ready to go. The ARES 5 kit includes 10mm and 25mm Plössl eyepieces, a red dot finder, and a simple alt-azimuth mount with rubber feet.

24 Orion StarShoot AllSky Camera

With its 180° fisheye lens, the StarShoot AllSky Camera can keep track of the sky from horizon to horizon. The company also designed the camera to withstand all conditions, so it can provide clear full-sky images any time. And the Sun overhead won't cause pixels to overload. The included video capture software also lets you display your sky in real time over the Internet, or you can take images to create amazing time-lapse movies.

25 Orion SteadyPix Adapter for iPhone

With this adapter from Orion, you can couple your iPhone3G, 3GS, iPhone 4, or 4S to any telescope's eyepiece to take photos of the Moon, planets, and even some bright deep-sky objects. Then you can share your results nearly instantaneously by email or social media. The adapter comes with a clamp to fit eyepiece housings up to 1.5 inches (38 millimeters) in diameter. Orion sells a larger clamp separately.

26 Quantum Scientific Imaging 583wsg CCD camera

QSI's top-end 583wsg camera uses Kodak's highly regarded 8.3-megapixel KAF-8300 full-frame CCD sensor, which has a photoactive array of 3326x2504 pixels. Other noteworthy features include mechanical and electronic shutters, a removable built-in filter wheel that accepts any standard 1¼" filter, and the company's Integrated Guider Port that picks off the light from a guide star in front of the filter. The company packs each camera in a Pelican case.

27 SBIG ST-i Monochrome Planet Cam and Autoguider

Looking for a compact CCD imager for capturing the planets? SBIG's ST-i model may be for you. Smaller and lighter than many standard 1¼" eyepieces, SBIG built the ST-i around Kodak's KAI-340 chip, which has a 648x484 pixel array. The built-in electronic shutter allows exposures as short as 0.001-second, while the integrated mechanical shutter can be used to generate dark frames. The ST-i also makes a great autoguider. Its fast f/2.8 optics allow you to guide on faint stars.

28 Sirius Astro Products Computer Cave

Many amateur astronomers bring laptops telescope-side, either as an imaging aid or for viewing star charts. But laptop screens, even overlaid with red gel, put out a lot of light. And they don't like dew. Enter the Computer Cave, a shield that encloses your laptop, reducing the light pollution it emits and protecting it from dew. Made of 6-mil corrugated plastic, the 24-inch by 18-inch by 18-inch (61cm by 46cm by 46cm) Cave quickly unfolds and assembles in seconds with Velcro strips.

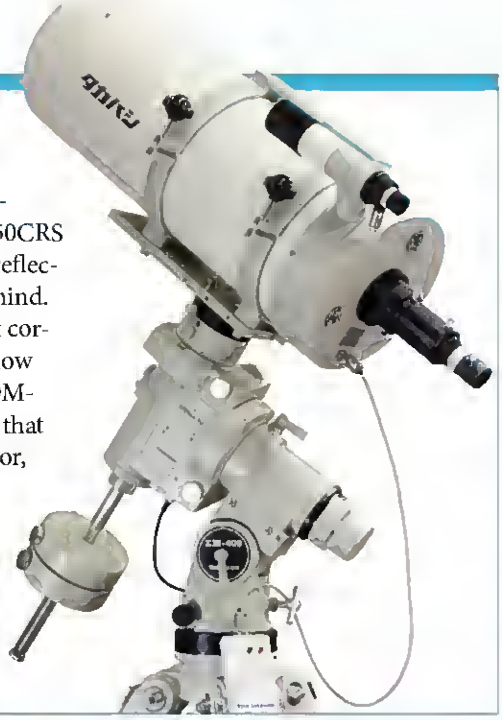
29 Southern Stars *SkySafari 3*

"There's an app for that" certainly rings true in observing. One of the most popular planetarium apps to come along recently is *SkySafari 3*. Available for iPhones, iPads, and iPod Touches using iOS 4 or later, *SkySafari 3* has three different levels. The Pro version will show you up to 15.3 million stars, 740,00 galaxies, and 550,000 solar system objects. It also will control your go-to telescope using optional cables or Wi-Fi modules.

30 *Starmap Pro*

Another popular app for iPhone and iPod Touch is *Starmap Pro* from France's Fredd. Not only does the app display the sky at any time, but it also lets you zoom in and out on objects and offers go-to telescope control, event calendars, and a night-vision mode. Most fun of all, *Starmap Pro* can identify stars and constellations in the sky when installed on devices with a built-in compass, like the iPhone 3GS. Hold your iPhone toward the sky, and *Starmap Pro* will identify the stars "behind" the phone.

31 Takahashi Mewlon-250CRS



Takahashi designed its 9.8-inch (250mm) Mewlon-250CRS Corrected Dall-Kirkham reflector with astroimaging in mind. Thanks to a three-element corrector lens made of extra-low dispersion glass, an ASCOM-compliant electric focuser that moves the secondary mirror, and a manual/automatic three-fan cooling system, the Mewlon 250CRS produces crisp flat-field views of solar system and deep-sky objects alike.

32 Teeter's Solid Tube Series

Designed with apertures of 8 and 11 inches and with moderate focal lengths, Teeter Solid Tube Series (STS) Newtonian reflecting telescopes are great for lunar and planetary observing. They also provide great views of binary stars and bright deep-sky objects. As with Teeter's truss-tubed scopes, their STS lineup combines outstanding workmanship with high-quality optics and materials to create heirloom-quality instruments. Each scope comes with a Dobsonian mount.

33 Tele Vue Delos series eyepieces

Mention eyepieces, and Tele Vue Optics is bound to pop into the minds of most amateur astronomers. Each Tele Vue Delos eyepiece — 3.5mm, 4.5mm, 6mm, 8mm, 10mm, 12mm, 14mm, or 17.3mm — features 20mm of eye relief and a 72° apparent field of view. The long eye relief means that even eyeglass-wearers get to enjoy the full field of view. And that field stays tack-sharp from edge to edge, whether you're viewing the Moon, planets, or your favorite deep-sky object.

34 Vixen Artes Binoculars

Vixen's Artes Binoculars, available in 8.5x45 and 10.5x45 models, feature extra-low dispersion fully multicoated lenses, phase coating on their BaK-4 roof prisms, long eye relief, and waterproof, nitrogen-filled barrels. Their no-compromise design guarantees exceptionally sharp images of all targets, whether terrestrial or celestial.

35 Vixen BT81S-A Binocular Telescope

Combining a pair of 3.1-inch f/5.9 refractors, Vixen's BT81S-A is ideal for anyone who — like me — thinks that two eyes are better than one. Magnesium-fluoride-coated air-spaced doublet objectives snap images into focus, while an optional alt-azimuth mount and tripod keep those views steady and secure.

Astronomy magazine
2012 Star Products

Astronomy's Star Products

#	COMPANY	PRODUCT	PRICE	WEBSITE
1	AG Optical	Newtonian astrographs	$6,695 to $20,195	www.agoptical.com
2	Astro Domes	Astro Dome 2400	$3,980	www.astrodomes.com
3	*Astronomy* magazine	*Astronomy Mogazine: The Complete Collection*	$149.95	www.Astronomy.com
4	Astronomy-Shoppe	The DobStand	$110	www.astronomy-shoppe.com
5	8inaryRivers	*BockyordEOS*	$30 ($38 with ASCOM plugin)	www.backyardeos.com
6	Catseye Collimation	Deluxe Triplepack XLK	$349 to $375	www.catseyecollimation.com
7	Celestron	CPC Deluxe 800 HD	$2,399	www.celestron.com
8	Celestron	Nightscape CCD Camera	$1,499	www.celestron.com
9	Celestron	SkyProdigy 6	$999	www.celestron.com
10	DobSTUFF	Makeover kits	$49S to $795	www.dobstuff.com
11	Explore Scientific	9mm 120° Series Argon-Purged Waterproof Eyepiece	$999.95	www.explorescientific.com
12	Explore Scientific	David H. Levy Comet Hunter	$1,199.99	www.explorescientific.com
13	Farpoint	Astro Armour Cases	$79.99 to $249	www.farpointastro.com
14	Hands on Optics	AstroTelescopes 102mm (4") f/11 Refractor	$599	www.handsonoptics.com
15	Hubble Optics	16" f/4.S Premium Ultra Light Dobsonian System	$2,995	www.hubbleoptics.com
16	Innovations Foresight	ONAG on-axis guider	$989	www.innovationsforesight.com
17	JMI Telescopes	ColliMotor	$259 to $289	www.jmitelescopes.com
18	Lunt Solar Systems	LS35T Hydrogen-alpha telescope	$598 to $749	www.luntsolarsystems.com
19	Meade Instruments	Series 5000 HD-60 eyepieces	$79.99	www.meade.com
20	Meade Instruments	LX80 Multi-Mount	$999	www.meade.com
21	Meade Instruments	LX800 Mount	$7,299	www.meade.com
22	Moonglow Technologies	All Sky Cam	$399.95 to $419.95	www.moonglowtech.com
23	Optics Planet	Bushnell ARES 5-inch Compact Truss Tube Dobsonian	$164.99	www.opticsplanet.net
24	Orion Telescopes and Binoculars	StarShoot AllSky Camera	$899.99	www.telescope.com
25	Orion Telescopes and Binoculars	SteadyPix Adapter for iPhone	$59.99	www.telescope.com
26	Quantum Scientific Imaging	QSI 583wsg CCD camera	$3,690	www.qsimaging.com
27	Santa 8arbara Instrument Group	ST-i Monochrome Planet Cam and Autoguider	$595	www.sbig.com
28	Sirius Astro Products	Computer Cave	$35.95	www.siriusastroproducts.com
29	Southern Stars	*SkySofori 3*	$2.99 to $59.99	www.southernstars.com
30	Starmap	*Stormop Pro*	$18.99	www.star-map.fr
31	Takahashi	Mewlon-250CRS	$9,250	www.takahashiamerica.com
32	Teeter's Telescopes	Solid Tube Series telescopes	$1,475 to $1,975	www.teeterstelescopes.com
33	Tele Vue Optics	Delos series eyepieces	$370	www.televue.com
34	Vixen Optics	Artes Binoculars	$999 to $1,099	www.vixenoptics.com
35	Vixen Optics	BT81S-A Binocular Telescope	$1,199	www.vixenoptics.com

SecretSky

by Stephen James O'Meara

M82: The "marquee" galaxy

An unexpected, almost electric display makes this star city an unusual target.

It's hard to come away from a star party without feeling inspired, especially from shared experiences with others. Consider the February 2012 Winter Star Party (WSP) in the Florida Keys, where Vic Menard of Bradenton, Florida, shared a peculiar visual phenomenon associated with starburst galaxy M82 in Ursa Major. If you sweep your eye across the galaxy's major axis, he said, beads of "starlight" pop in and out of view like "twinkle lights on a Christmas tree." The puzzle is that images of M82 show no obvious stars projected against the galaxy's bright center.

Menard first noticed the phenomenon at the 2010 WSP while enjoying a view of M82 through his 22-inch f/4 Dobsonian reflector at 321x. Among the numerous tendrils of dust near the galaxy's eruptive center, his eye caught sight of a curious "dark bay with a solitary star near its center." Under sharper focus, he detected several dimmer "*very* small" stellar points nearby.

Suddenly, these points "winked out of view," only to be replaced by others "ever so slightly peripheral" to the first ones. Menard and his companions could see anywhere from six to a few dozen of these "twinkling" lights.

At the 2012 WSP, I counted seven of these mysterious spots through the same scope at the same power. And when I let my eye drift about, these lights flickered in and out of view along the galaxy's major axis, like a row of chasing lights in a marquee. What was going on?

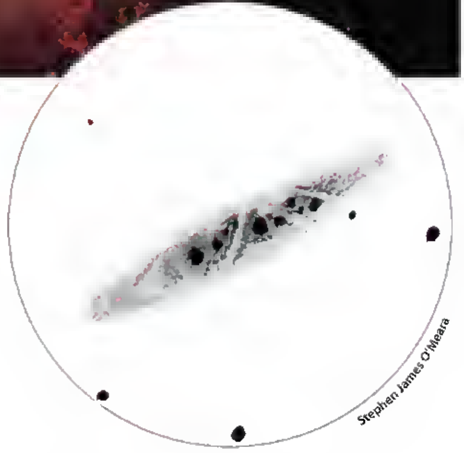
Some of this, some of that?

I proffer the possibility of a brightness-contrast illusion, coupled with flickering effects resulting from the shifting of averted vision while scanning.

Certainly, the view of M82 through Menard's large and finely collimated reflector was spectacular — a mottled mess of light patches and dark streaks squeezed into a fuzzy cigar-shaped disk that dominated the field of view. The veins of

NASA/ESA/Hubble Heritage Team (STScI/AURA)

▲ **Starburst galaxy M82** shines spectacularly in this Hubble Space Telescope image; spying it through a backyard scope, on the other hand, can reveal what seem like secret shimmering stars.



Stephen James O'Meara

▶ **The unexpected "stars"** glittering along M82's major axis (sketched here through a 22-inch scope at 321x) may be the result of bright gas poking irregularly through darker dust lanes.

darkness formed an irregular scrim through which mismatched patches of extragalactic light burned forth in a linear (though slightly wavy) fashion.

The mysterious "star fire" in M82 appears to be glowing gas peeking through these dusty filaments, which may also enhance their contrast. "A white spot surrounded by a dark environment will appear brighter as the latter is darkened," explained Matthew Luckiesh in his 1922 book, *Visual Illusions: Their Causes, Characteristics and Applications*. In M82's case, the light and dark regions seem to reinforce each other in such a way as to create flickering "stars" where none exist.

The effect appears roughly linear because we see the enhanced spots along the major axis of this nearly edge-on system, like dew drops reflecting sunlight on a blade of grass. The "stars" turn on and off successively in brightness because we're shifting our gaze from averted to more direct vision, respectively, during the visual sweeps.

In 2011, Menard and his wife, Lynne, observed a similar twinkling network of stellar points around the star formation areas in the Box Galaxy (NGC 4449) in Canes Venatici. "Again," he said, "we've observed this galaxy numerous times before in various apertures and magnifications, and we had never seen this."

I'd like to know if you can detect this phenomenon in M82, or other galaxies, through smaller apertures. As always, let me know what you see and think at someara@interpac.net.

Browse the "Secret Sky" archive at www.Astronomy.com/OMeara.

See reports on 350+ products at www.Astronomy.com/equipment.

Attention manufacturers: To submit a product for this page, email **mbakich@astronomy.com.**

1¼" eyepiece

Tele Vue Optics
Chester, New York

Tele Vue Optics' Delos EDL-03.5mm eyepiece has a 72° apparent field of view and 20mm of eye relief. The company applies matched multicoatings to each optical surface. The unit weighs 1.1 pounds (499 grams) and features an adjustable eyeguard system.

Price: $370
[t] 845.469.4551
[w] www.televue.com

Camera cooler

Orion Telescopes and Binoculars
Watsonville, California

Orion's DSLR Camera Cooler chills imaging sensors for Canon 1100D, 1000D, 550D, 500D, 450D, 400D, and 350D cameras. The 51-watt Peltier cooler lowers the temperature inside in the insulated chamber up to 43° Fahrenheit below ambient.

Price: $399.99
[t] 800.447.1001
[w] www.telescope.com

Filter wheel

Orion Telescopes and Binoculars
Watsonville, California

Orion's 5-Position 1.25" Filter Wheel holds up to five 1¼" filters. The design protects installed filters or eyepieces from dust, dirt, and impact. The device requires an additional 0.79 inch (20 millimeters) of focus travel.

Price: $99.99
[t] 800.447.1001
[w] www.telescope.com

1¼" eyepiece

Meade Instruments
Irvine, California

Meade's Series 5000 9mm HD-60 1.25" eyepiece offers a 60° apparent field of view and more than 17mm of eye relief. It delivers a 40 percent improvement in corrections for chromatic aberration and edge distortions over traditional Plössl eyepieces.

Price: $79.99
[t] 800.626.3233
[w] www.meade.com

T-adapter

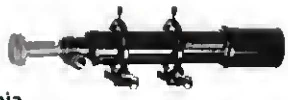
Celestron
Torrance, California

Celestron's T-Adapter for 925, 1100, and 1400 EdgeHD optical tubes threads onto the telescope's rear cell. This device lets you attach your 35mm camera to the prime focus of your scope. The T-Adapter does require the proper T-ring (not included), which is specific to your camera.

Price: $54.95
[t] 310.328.9560
[w] www.celestron.com

AP THEORY

Guide scope



Celestron
Torrance, California

Celestron's 80mm Guidescope Package includes a 3.1-inch (80mm) guide scope and 125mm mounting rings. A metal focuser with a tension screw minimizes mechanical play. The included extension tube lets you achieve focus without a diagonal. The unit is compatible with the company's NexGuide Autoguider.

Price: $189.95
[t] 310.328.9560
[w] www.celestron.com

by Tony Hallas

How I take pictures

Learn from a master the step-by-step process behind creating a beautiful astroimage.

Over the years, many people have asked me to detail my "work flow." They want to know: How do I take a picture? That may seem like a simple question, but, unfortunately, there is no easy answer because every image (as beginners soon discover) has its own personality.

In a perfect world, however, I try to follow a pattern. I begin by analyzing the nature of my target. Does it need deep exposures to allow massive stretching (see my November and December 2010 columns), or is it a bright nebula (like the Rosette) where short exposures will do? This will dictate whether I shoot 90- or 15-minute exposures and whether I combine 25 or five.

Do I shoot a separate luminance that I'll combine with RGB data (my typical procedure for a galaxy) with my 14.5-inch f/9 reflector, or do I simply shoot RGB images (like I do for most nebulae) with my 71mm f/5.6 refractor? Tailoring your equipment and imaging parameters to the subject matter is the first step toward achieving superior results.

Once I have enough exposures, I go through and reject the worst. Issues like inferior seeing, bad guiding, or focus still crop up in some shots despite my best efforts.

After narrowing my selection, I use *MaxIm DL* version V to apply my darks and flats (see my September 2010 column), and to combine the pictures. I'm a big fan of the multi-iterative "SD Sigma Combine" for my combining, and I save the resulting 16-bit FITS file as a "master" file of the respective images. I also use *MaxIm DL* to align and combine my color frames into a master RGB, saved in 16-bit FITS. (For more about this process, see my January 2011 column.)

From here, I use a software algorithm on these master files that reverses the blur mostly caused from poor seeing and sharpens the images. (My favorite software for this process, called deconvolution, is AIP4WIN.)

Browse the "Imaging the Cosmos" archive at www.Astronomy.com/Hallas.

All photos: Tony Hallas

The Triffid Nebula (M20), shown here, is among the brightest targets in the sky, along with other summer nebulae like M8 and M17. Because of this, only short shots are necessary. For this image, the author took five RGB exposures 10 minutes in length. As always, knowledge of the subject matter is required to achieve good results.

▶ **M27 is a bright planetary nebula,** so it too provides a lot of light. Nine frames of 20-minute RGB exposures, combined with nine frames of 30-minute exposures of Hydrogen-alpha light, were all it took to create this image.

Next, I bring these files back into *MaxIm DL* and convert them to 16-bit TIFF files. The advantage of this is that I can compress the files linearly to fit within the 16-bit boundaries if necessary.

When I am satisfied with my data reduction, I import the files into *Photoshop CS5* to stretch the data using "Curves." I also use "Levels" to reset the black point because "Curves" brightens the image. Once I have the stretched versions of the luminance and RGB, I use *Photoshop* to clean up the images. This might include removing satellite or airplane trails, adjusting color gradients, and dealing with any vignetting. Then, all that remains is the "fun" part: emphasizing the subtle elements of the image and using noise reduction to smooth it out.

Sometimes after my first "journey" through the data, I realize a different approach would work better. With difficult photos, I rework the image several times, slowly "getting to know" the data and the image better. This is common — accomplished imagers often realize that the best approach to the processing only becomes obvious after the first try. So don't feel discouraged if your initial attempt didn't come out perfect. Just go back and make it better.

Making an A-grade image requires many steps. As with so much, you'll find that good planning will help considerably.

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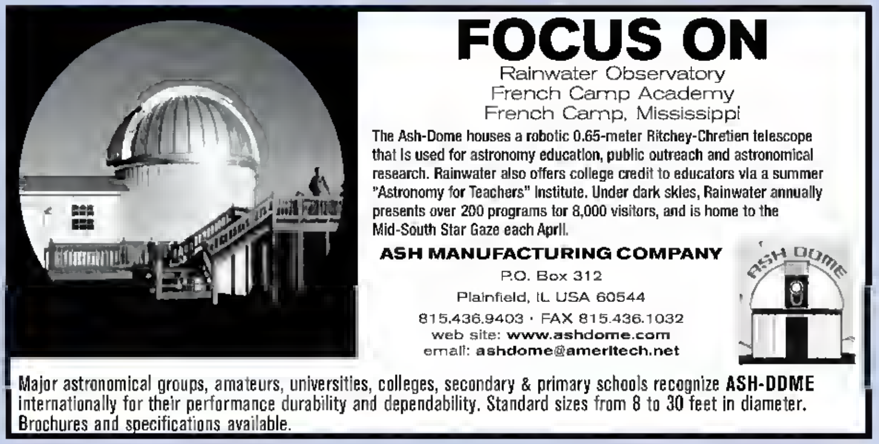
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INDEX *of* ADVERTISERS

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Ring of fire

The annular eclipse that occurred May 20, 2012, was the target of thousands of astroimagers and millions of casual viewers. Conditions were ideal across much of the Western United States, so most people who wanted to view it experienced warm temperatures and plenty of clear skies overhead. This 25-exposure montage shows the event from beginning to end. The imager set his DSLR to shoot automatically with a self-timer. He covered his lens with Baader AstroSolar film, but he removed it for the last shot, which shows sunset. The next annular eclipse visible from the United States occurs October 14, 2023.

An annular solar eclipse (Canon EOS Digital Rebel XTi DSLR, Canon 17mm lens at f/8, ISO 200, 1⁄250-second exposures, taken May 20, 2012, from Page, Arizona) • Chris Schur, Payson, Arizona

▶ **Reflection nebula Sharpless 2–73** is a molecular cloud in the constellation Hercules the Hero. It lies nearly 400 light-years away and contains between 20 and 40 solar masses. (5.2-inch Takahashi TOA-130 apochromatic refractor at f/6, SBIG STL-11000M CCD camera, LRGB image with exposures of 360, 165, 165, and 165 minutes, respectively) • Alistair Symon, Marana, Arizona

The May 2012 annular solar eclipse allowed for a vast array of image types. Wide-field photos were common, as were individual shots through telescopes and long-focal-length lenses, as in this case. (Nikon D300 DSLR, 400mm Nikon lens with a 2x extender, giving an effective focal length of 600mm, f/8, $1/250$-second exposures, taken May 20, 2012, from Monument Valley, Utah) • Ben Cooper/ LaunchPhotography.com

The so-called "super Full Moon" of last May rises above the Temple of Poseidon in Cape Sounion, Greece. The monument perches 200 feet (60 meters) above the Aegean Sea. (Nikon D700 DSLR, Nikon 70–300mm lens at f/8, combination image with a $1/125$-second exposure for the Moon and a $1/25$-second exposure for the temple, taken May 5, 2012, from Cape Sounion, Greece) • Matsopoulos N. Theofanis, Zagori, Greece

The Double Cluster (NGC 869 and NGC 884) in Perseus is a favorite target among astroimagers, but most shots of it are close-ups. This image, however, shows the two open clusters in a wide field surrounded by red emission nebulosity. (Tele Vue NP-101is apochromatic refractor at f/5.4, SBIG STL-11000M CCD camera, HαLRGB image with exposures of 22, 1.15, 1, 1, and 1.15 hours, respectively) • Fabian Neyer, Abtwil, Switzerland

Send your images to: *Astronomy* Reader Gallery, P. O. Box 1612, Waukesha, WI 53187. Please include the date and location of the image and complete photo data: telescope, camera, filters, and exposures. Submit images by email to readergallery@astronomy.com.

reader gallery

Strange planetary conjunctions are a favorite of this South American imager. Here, the Moon, Mercury, Uranus, and the deep-red carbon star TX Piscium all lie in the same region of sky an hour before sunrise. At the time of this image, the Moon was a waning crescent that floated within the Circlet asterism of the constellation Pisces the Fish. (Canon 5D Mark II DSLR, Canon 24–105mm lens set at 73mm and f/4, ISO 3200, 1.6-second exposure, taken April 18, 2012, at 6:21 A.M. local time, from Buenos Aires, Argentina) • Luis Argerich, Buenos Aires, Argentina

The Cosmic Grid

All things high, low, weird, and wonderful in astronomy and space science. **by Bill Andrews**

WEIRD

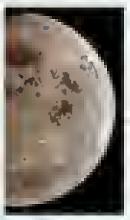
Moon motor
European researchers announce a new ultra-compact motor capable of lunar transport on just 0.1 liter of fuel. Has the future finally arrived?

No thanks, money
The Giant Magellan Telescope Organization declines an opportunity for National Science Foundation funds, despite still needing money to complete the project. How … brave?

Cinematic star city
The UK Space Agency refers to galaxy Centaurus A as a "cannibalistic galaxy with a powerful heart," which sounds more like a movie tagline.

Martian microbes
Researchers studying 36-year-old martian soil samples from the Viking missions claim they've found evidence of life; if so, we've finally figured out who saw *John Carter*.

No planetary privacy
British scientists reveal the native sounds of Venus and Mars, presumably after the planets' cellphones got hacked.



Lunar shock
The University of Chicago in Illinois announces, "Titanium paternity test fingers Earth as moon's sole parent." Gosh, I hope this isn't how the Moon finds out.

Cometary catastrophe
Next time on *CSI: Milky Way*: the grisly tale of a "comet massacre" around nearby star Fomalhaut, courtesy of the European Space Agency.

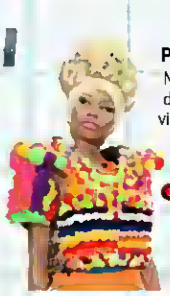
Aurorae on Uranus
In dismaying news to everyone named Aurora, astronomers photograph the glowing lights on Uranus.

Space, now with dinosaurs
A study in the *Journal of the American Chemical Society* suggests that advanced dinosaurs may rule over other planets. It didn't make any more sense in context.

HOT

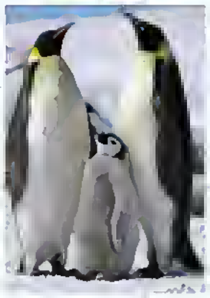
NOT

New York to *Enterprise*
A space shuttles flies once more — sort of. *Enterprise* soars above New York while snuggly mated to its 747 Shuttle Carrier Aircraft.

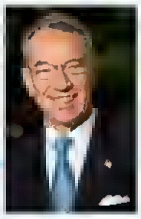


Pop astronomy
Nicki Minaj finally drops her latest video, "Starships," rewarding the patience and increasing desperation of fans (unlike real starships).

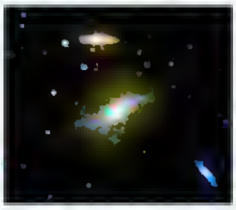
Space-eye view
Science has reached the point where it's easier to count penguins from space with satellites than actually going to Antarctica.



Godspeed, Geoff!
Legendary exoplanet hunter Geoff Marcy decides to try his luck in another kind of hunt, as the next Chair in the Search for Extraterrestrial Intelligence at the University of California, Berkeley.



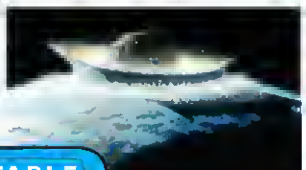
Senatorial space secrets
U.S. Senator Charles Grassley asks NASA about its alleged spilling of state secrets. Not quite the renewed congressional interest in space we were hoping for.



Space blows
NASA compares the behavior of supernovae and black holes to a leaf blower; way to capture the unimaginable beauty and wonder of the cosmos, folks.

Time travel-ish?
The University of California, Los Angeles, calls its new infrared spectrometer "a 'time machine' of sorts," which would be truly amazing if it were.

Wow, space huh?
The International Space Station will receive an addition in 2014 allowing for "low-cost access to space." I remember when that was the space shuttles' job.



I have cosmophilia
The approaching Mayan deadline of 2012 occasions the sudden rise of the Internet's most communicable disease: cosmophobia, the fear of astronomical events.

PREDICTABLE

PHOTOGRAPHS: EPFL News (Moon motor); GMTO (No thanks, money); Far-infrared: ESA/Herschel/PACS/SPIRE/C. D. Wilson (MacMaster University); X-ray: ESA/XMM-Newton/EPIC; Visible: ESO/MPG (Cinematic star city); NASA (Martian microbes); NASA (planets); iStockphoto/Thinkstock (ears) (No planetary privacy); NASA (Lunar shock); ESA/Herschel/PACS/Bram Acke (KU Leuven) (Cometary catastrophe); NASA/Laurent Lamy (Aurorae on Uranus); iStockphoto/Thinkstock (Space, now with dinosaurs); United States Senate (Senatorial space secrets); NASA/JPL-Caltech/SDSS/NRAO/ASIAA (Space blows); NASA (Wow, space huh?); NASA/Don Davis (I have cosmophilia); NASA/KSC (New York to *Enterprise*); Christopher Macsurak (Pop astronomy); Ian Duffy (Space-eye view); NASA (Godspeed, Geoff)

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- Minor in Astronomy

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Darkness Down Under

When I started out in astronomy, it was great fun to "discover" the planets — to learn which of the bright points of light in the sky were members of the solar system. I found it particularly exciting to identify elusive **Mercury**, which only appears low in the evening or morning sky.

And I still find it exhilarating to glimpse the innermost planet. You can enjoy the same thrill early this month as Mercury wraps up its best evening appearance of 2012. Although the planet reached greatest elongation from the Sun in late October, the best views through a telescope come as its distance from Earth decreases during the first ten days of November. Plan to observe about 45 minutes after sunset, when the sky has started to darken noticeably and Mercury still lies several degrees above the western horizon.

On November 1, Mercury appears 7" across and half-lit. By the 10th, its disk spans 9" and reveals a 20-percent-lit phase. The crescent shape shows up nicely through moderate apertures. Mercury disappears in the twilight soon thereafter, passing between the Sun and Earth at inferior conjunction November 17.

Mars has been a fixture in the evening sky since March. This month, it lies in the west as darkness falls, to the right of Scorpius the Scorpion's tail. The Red Planet is easy to identify because of its distinctive color. Compare it with Antares, Scorpius' brightest star, which lies well to Mars' lower left. Both shine at 1st magnitude and exhibit a ruddy hue. When viewed through a telescope, Mars' 4"-diameter disk appears featureless.

As darkness settles in, you can find **Jupiter** rising in the northeast. The largest of the Sun's planets shines at magnitude –2.8 and easily dominates the background stars of Taurus the Bull. The planet looks dazzling by midevening.

For the best view of Jupiter through a telescope, wait until it climbs reasonably high in the late-evening sky. The planet's disk spans 48" across its equator in mid-November and 45" through the poles — a difference that's easy to see with small instruments. Also look for two dark belts that run parallel to each other, one on either side of a brighter equatorial zone.

The remaining planets reside low in the predawn sky. **Venus** rises about 90 minutes before the Sun. The brightest planet shines at magnitude –3.9 and appears as a beacon low in the east. Unfortunately, it doesn't gain much altitude in the twilight sky. Like Mars, Venus proves to be disappointing through a telescope. Its disk measures only 12" across and appears nearly full.

Saturn reappears in the morning sky in late November. On the 27th, it and Venus lie only 0.6° apart. Venus shows up without a problem, but you might need binoculars to spot the ringed planet this low in the sky. Saturn then shines at magnitude 0.7, less than 2 percent as bright as Venus.

The month's biggest highlight comes November 13/14, when the Moon passes in front of the Sun and creates a **total solar eclipse**. Northern Queensland in Australia will be the center of the astronomical universe that day. Shortly after the Sun rises on the 14th, the Moon completely blocks the Sun from view for up to 2 minutes and 5 seconds. See "2012: a historic year for solar eclipses" in the March issue for details about this event.

A **penumbral lunar eclipse** occurs November 28. Residents of Australia and New Zealand have ringside seats for this event, which begins at 12h15m Universal Time (UT) and peaks at 14h33m UT. At maximum, 92 percent of the Moon's diameter will lie within Earth's penumbral shadow, causing the Moon's northern half to darken slightly.

The Moon occults Jupiter twice this month. On November 2, observers in southern Africa have the best view. From Cape Town, Jupiter disappears at 0h36m UT and reappears at 1h52m UT. People in southern Africa and much of southern South America can witness the November 28/29 occultation. From Rio de Janeiro, Jupiter disappears at 23h11m UT and reappears at 0h14m UT.

The starry sky

On spring evenings, Crux the Southern Cross dips low in the sky, appearing upside down just above the southern horizon. In much of the Southern Hemisphere, Crux is a circumpolar constellation, which means that it never sets. But that's not true from everywhere south of the equator.

Gacrux, the northernmost of the Cross' stars, has a declination of –57.1°. So, the Cross is circumpolar only for latitudes south of 32.9° south. But this won't always be the case. I recently pondered the question of what the sky will look like in the distant future as the position of the Cross changes.

Earth's axis precesses like that of a spinning top. Over a period of approximately 26,000 years, the axis traces a large circle on the sky. And, because the axis points toward the celestial poles, they also move with respect to the stars.

Currently, the Southern Cross is heading southward. It will be at its most southerly position around the year 5900, when Gacrux's declination will reach –74.6°. This will make it circumpolar for latitudes south of 14.4° south, which includes almost all of Australia, Fiji, and the southern third of Brazil.

At the opposite extreme, Acrux (the brightest Cross star) will push farthest north around the year 18,600, when it achieves a declination of –29.4°. This will make the Cross visible — at least parts of it at certain times — from the southern parts of Canada and Scandinavia. By then, however, the motions of these stars relative to one another will have changed Crux's appearance so it looks less like a cross.

StarDome

The all-sky map shows how the sky looks at:
11 P.M. November 1
10 P.M. November 15
9 P.M. November 30

Planets are shown at midmonth

How to use th
latitude. Loca
east, a
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his map: This map portrays the sky as seen near 30° south ted inside the border are the four directions: north, south, nd west. To find stars, hold the map overhead and orient it o a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

Star colors: Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.

Illustrations by *Astronomy*: Roen Kelly

November 2012

Calendar of events

1 The Moon is at apogee (406,050 kilometers from Earth), 15h29m UT

2 The Moon passes 0.9° south of Jupiter, 1h UT

7 Last Quarter Moon occurs at 0h36m UT

Mercury is stationary, 4h UT

11 Neptune is stationary, 11h UT

The Moon passes 5° south of Venus, 18h UT

12 The Moon passes 0.8° south of Spica, 2h UT

The Moon passes 4° south of Saturn, 21h UT

13 New Moon occurs at 22h08m UT; total solar eclipse

14 The Moon is at perigee (357,361 kilometers from Earth), 10h22m UT

15 Venus passes 4° north of Spica, 23h UT

16 The Moon passes 4° north of Mars, 10h UT

The Moon passes 0.1° north of Pluto, 23h UT

17 Leonid meteor shower peaks

Asteroid Pallas is stationary, 14h UT

Mercury is in inferior conjunction, 16h UT

20 First Quarter Moon occurs at 14h31m UT

The Moon passes 6° north of Neptune, 22h UT

23 The Moon passes 5° north of Uranus, 14h UT

26 Mercury is stationary, 20h UT

27 Venus passes 0.6° south of Saturn, 5h UT

28 Full Moon occurs at 14h46m UT; penumbral lunar eclipse

The Moon is at apogee (406,362 kilometers from Earth), 19h37m UT

29 The Moon passes 0.6° south of Jupiter, 1h UT

For definitions of terms, log onto www.Astronomy.com/glossary.